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# The Consequences Of Low Birthweight

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# THE CONSEQUENCES OF LOW BIRTHWEIGHT

by

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Abstract

An extensive literature investigating the consequences of low birthweight for childhood development has focused on group differences and the prediction of global cognitive outcomes. The purpose of this thesis was to identify factors that predict specific childhood outcomes and to consider explanatory models of the role of early medical risk for childhood language, motor and attention outcomes. Ninety low birthweight children participating in a prospective longitudinal study were assessed at 5 1/2 years of age. Although there were no consistent differences between within-sample medical risk subgroups on the childhood outcome measures, regression analyses demonstrated that both early medical risk and environmental factors must be considered in prediction, as the predictive utility of these factors varied for different childhood outcomes. Medical risk predicted motor outcome, whereas infant environmental factors predicted language and attention outcomes. Path analyses of models of language, motor and attention outcomes suggested that both early medical risk and infant environmental factors had an indirect effect on childhood outcomes, and that the effects of these factors, infant developmental status, and the quality of the childhood environment vary for different outcomes. The relations between these models and underlying developmental processes were discussed, as were implications for future research.

To my parents.

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The Consequences of Low Birthweight

**Purpose**

There is an extensive literature investigating the consequences of low birthweight (<2500 grams) for subsequent child development. Three purposes are evident in this literature. One purpose has been descriptive, comparing low birthweight and normal birthweight samples on childhood outcome measures. The role of birthweight has been inferred on the basis of group differences in outcomes, usually global measures such as IQ. More recently, specific outcomes such as language, motor skills, and attention have been considered. A second purpose has been to predict childhood outcome and has involved the identification of variables, such as medical risk and environmental conditions, that predict subsequent development. The prediction of global, rather than specific, childhood outcomes has been most frequent. A third purpose has been explanatory, and has involved the formulation of a model of the development of low birthweight children, often as a prototypical medical risk group. Child and environmental factors that may mediate the impact of early medical risk on subsequent development have been the focus.

Despite the recognized need for research emphasizing prediction and explanation (Cohen, 1986; Hoy, Bill, & Sykes, 1988; Kopp, 1983; Scott, 1987), there has been limited work with these purposes. Therefore, the purpose of the present study was to identify factors that predict specific outcomes during childhood and to consider explanatory models of the role of early medical risk for these outcomes.

Overview

The report of the current study will consist of three chapters: description; prediction; and explanation.

Description. The purpose of the description chapter will be to provide a rationale for the measures used in the current study and to compare childhood outcomes to results reported in the research literature. Recent research that has described childhood outcome among low birthweight infants will be summarized. A description of global and specific outcomes among the children participating in the current study will then be presented and discussed.

Prediction. After a summary of research on the prediction of childhood outcomes among low birthweight children, aggregate predictor and outcome measures will be derived from data collected in the current study. These aggregated measures will be used to predict global and specific childhood outcomes.

Explanation. Models of potential causal relations among child and environmental factors for three specific outcomes will be formulated on the basis of previous research. The utility of each model will then be evaluated and discussed.

## Chapter 1

### The description of childhood outcomes

Research describing the consequences of low birthweight has an extensive history (Benton, 1940; Caputo & Mandell, 1970; Shirley, 1939), but has been complicated by the heterogeneity of the low birthweight population. Before 1961, the term premature was used to refer to infants born weighing 2500 g or less. However, the terminology was refined by the World Health Organization in 1961 (Cohen, 1986). The term low birthweight refers to infants born weighing 2500 g or less. Preterm refers to infants born with a gestational age equal to or less than 37 weeks. Although many low birthweight infants are also preterm infants, the two terms are not synonomous.

Within the low birthweight population, there are also different subgroups that may be designated on the basis of specific medical risk factors. For example, there are very low birthweight (<1500 g) and extremely low birthweight (<1000 g) infants. Furthermore, the presence and severity of neonatal illness is strongly related to low birthweight, although the risk for a specific illness may differ for different birthweight subgroups (Cohen, 1986). This heterogeneity has influenced the comparability of the results of different studies and complicated interpretations of the consequences of low birthweight for child development.

A brief history of the research describing outcomes will first be presented. The review of recent research will focus on the results of studies of low birthweight children born since 1975 and assessed between 3 and 7 years of age. Recent findings concerning global cognitive outcomes and the specific outcomes of language, motor and attention skills will be summarized. The implications of this research for the current study will then be presented.

History. Changing conditions of medical care and practice have been important to an understanding of this research, as there is a consensus that the major consequences of low birthweight have varied with the era of the cohort (Cohen, 1986; Hack, Fanaroff, & Merkatz, 1979; Hoy et al., 1988; Kopp, 1983). However, despite the influence of secular changes on rates of mortality and handicapping conditions, similar themes have emerged across all eras of research. There has been a marked variability in childhood outcome within each era of studies (Benton, 1940; Hoy et al., 1988; Kopp, 1983). Low birthweight has been associated with slightly lower IQ scores that may or may not be significantly different from a comparison group (Scott, 1987). The role of environmental factors, either as confounding variables (such as socioeconomic status) or mediating variables (such as the quality of caretaking) has been acknowledged (Cohen, 1986; Siegel, 1984a).

During the first part of the 20th century, the mortality rate was high, although there was a low rate of major handicap, such as mental retardation, among survivors (Cohen, 1986). In a review of these studies, Benton (1940) noted marked variability in research results, as reports of normal cognitive outcome among low birthweight children were common, although there were also some reports of poor outcomes. He considered that these differing reports might be related to the use of unreliable outcome measures, and to methodological factors such as small samples and selection biases. However, Benton (1940) concluded that environmental factors, such as socioeconomic status, were not adequately described and that discrepant findings might be attributable to differences in environmental conditions, rather than to medical risk alone.

Due to changes in the nature of medical practice, there was a significant decrease in mortality rates during the 1950's and early 1960's (Cohen, 1986), but a relatively high rate of major handicaps among survivors (Stewart, Reynolds, & Lipscomb, 1981). For example, Drillien (1958, 1964) reported that only 37% of her very low birthweight sample scored 90 or over on an early childhood intelligence test. However, she observed that environmental factors were related to childhood outcome, as, children in the lower socioeconomic group had relatively lower scores.

During the late 1960's and early 1970's, the period of the introduction of neonatal intensive care, there was a decrease in rates of mortality and major handicap. For example, Drillien, Thomson, and Burgoyne (1980) studied a second cohort and reported, in contrast to Drillien's earlier study, that 77% of the children scored 90 or over on an early school-age intelligence test. Once again, however, Drillien et al. (1980) observed that mean IQ scores decreased with socioeconomic status.

Beginning in the mid to late 1970's, a period of change in neonatal intensive care practice, there has been a continued decrease in mortality rates. The overall rate of major handicap has not significantly changed (Murphy, Nichter, & Liden, 1982), although there has been considerable variability in reports across studies (Hoy et al., 1988). The general finding of this most recent era of research has been that the childhood cognitive outcome of many low birthweight infants is within the normal range and close to that of normal birthweight children (Aylward, Pfeiffer, Wright, & Verhulst, 1989; Hoy et al., 1988). However, an increased risk for minor deficits -- poor performance on specific outcomes such as language, motor skills, and attention -- has been reported (Cohen, 1986). Furthermore, the importance of environmental factors has continued to be acknowledged, even among the highest medical risk groups. For example, Hirata et al. (1983) observed that among their sample of extremely low birthweight children (<750 g), developmental status during early childhood was related to socioeconomic status. Children in the lowest socioeconomic group had lower developmental test scores ($\underline{M}$=79) relative to children in the middle ($\underline{M}$=95) and highest ($\underline{M}$=110) socioeconomic groups.

Global cognitive outcome. The most commonly used global measure of cognitive outcome has been IQ. The mean IQ scores of low birthweight samples have consistently been within the normal range during early childhood (Astbury, Orgill, & Bajuk, 1987; Astbury, Orgill, Bajuk, & Yu, 1990; Cohen & Parmalee, 1983; Crisafi, Driscoll, & Fleiss, 1989; Escalona, 1982; Ford, Steichen-Asch, Babcock, & Fogelson, 1989; Kitchen et al., 1982; Kitchen, Doyle, Ford, Rickards, Lissenden, & Ryan, 1987; Leonard, Clyman, Piecuch, Juster, Ballard, & Behle, 1990; Marlow, Roberts, & Cooke, 1989; Nickel, Forrest, Bennett, & Lamson, 1982; Rose & Wallace, 1985a, 1985b; Ross, Lipper, & Auld, 1985; Wallace, Escalona, McCarton-Daum, & Vaughan, 1982). When comparisons between birthweight subgroups within a low birthweight sample have been made, there have been inconsistent reports of significant subgroup differences. For example, Cohen & Parmalee (1983) reported that there was no significant difference between the mean Stanford Binet IQ scores of low birthweight and very low birthweight subgroups within their demographically diverse sample. However, there have been reports of significantly lower mean IQ scores for extremely low birthweight (<1000 g) children relative to other children in a low birthweight sample (Crisafi & Driscoll, 1989; Hunt, Tooley, & Harvin, 1982; Mazer, Piper, & Ramsay, 1988; Resnick et al., 1990; Teberg et al., 1982).

The same inconsistencies in results have been noted among studies that have included a normal birthweight comparison group, with some studies reporting no group differences and IQ scores within the normal range during early childhood (Grigoroiou-Serbanescu, 1981; Holmes, Reich, & Rieff, 1988; Holwerda-Kuipers, 1987; Klein, 1988; Michelsson, Lindahl, Parre, & Helenius, 1984; Nickel et al., 1982; Silva, McGee, & Williams, 1984), and others reporting significantly lower mean scores on IQ measures for low birthweight children (Lloyd, Wheldall, & Perks, 1988; Marlow et al., 1989; Matilainen, Heinonen, & Siren-Tiusanen, 1988; McDonald, Sigman, & Ungerer, 1989; Michelsson et al., 1984; Vohr & Garcia-Coll, 1985).

Alternative global measures of cognitive outcome have been used and yielded similar inconsistent results. The most common of these has been the McCarthy Scales of Children's Abilities (McCarthy, 1972), that yields an index of general cognitive development (the GCI) that is highly correlated with Stanford-Binet and Wechsler IQ measures (McCarthy, 1972). Mean GCI scores for low birthweight children have sometimes been within the normal range (Field, Dempsey, & Shuman, 1983; Harvey, Prince, Bunton, Parkinson, & Campbell, 1982; Jacob, Benedict, Roach, & Blackledge, 1984; Saigal, Szatmari, Rosenbaum, Campbell, & King, 1990; Siegel, 1982a, 1982b; Williams, Lewandowski, Coplan, & D'Eugenio, 1987), and sometimes been significantly lower for higher medical risk subgroups within a low birthweight sample (Saigal et al., 1989; Williams et al., 1987). Similarly, some studies have reported no significant differences between the mean GCI scores of low birthweight and normal birthweight groups (Jacob et al., 1984), while other studies have reported normal GCI scores among low birthweight samples that were significantly lower than those of normal birthweight comparison groups (Field et al., 1983; Pfeiffer & Aylward, 1990; Siegel, 1982a).

In summary, there have been consistent reports of mean scores within the normal range on global cognitive outcome measures such as IQ or McCarthy GCI. There have been inconsistent reports of reliable differences in global cognitive outcome between birthweight subgroups within a low birthweight sample, and between low birthweight children and a normal birthweight comparison group. These conclusions parallel those of a meta-analysis of recent low birthweight followup studies (Aylward et al., 1989). Although within sample comparisons were reported in only one-third of the reviewed studies, there were no statistically significant differences between the combined mean global cognitive scores of birthweight subgroups (Aylward et al., 1989). Furthermore, although the combined mean global cognitive score of low birthweight children ($M$ = 97.8) was significantly lower than the mean of normal birthweight children ($M$ = 103.8), Aylward et al. (1989) suggested that the clinical significance of this difference could be minimal.

Specific cognitive outcomes

Overview. The exclusive focus on global measures such as IQ has been criticized in recent reviews of the low birthweight literature (Aylward et al., 1989; Cohen, 1986; Kopp, 1983). This criticism has resulted, in part, from concerns over the clinical significance of global cognitive outcomes. Furthermore, reports of specific deficits despite normal global cognitive outcome suggest that specific aspects of functioning should be more adequately described (Aylward et al., 1989). For example, Hunt et al. (1982) reported that 72% of the very low birthweight children in their middle class sample had normal Stanford-Binet IQ scores during early childhood. However, 25% of the normal IQ children were rated as abnormal due to poor performance on measures of language and/or motor skills. Furthermore, 20% of the normal IQ children rated as suspect were rated so because of distractibility and/or poor impulse control. Therefore, specific childhood outcomes -- such as language, motor skills and attention -- have received increasing attention in the descriptive research literature (Aylward et al., 1989).

Language outcome. Language skills represent an important aspect of functioning during early childhood and may be an important predictor of subsequent school achievement (Horn & Packard, 1985; Simner, 1983). Most studies of early childhood language outcome among low birthweight children have included standardized psychometric measures. However, a wide variety of measures has been used, including verbal scale scores obtained from tests such as the WISC-R or the McCarthy Scales, and scores from specialized tests of language skills and reading achievement.

Among studies of low birthweight samples, there have been fairly consistent reports of mean scores within the normal range on measures of verbal IQ (Astbury et al., 1987, 1990; Nickel et al., 1982; Rose & Wallace, 1985a, 1985b; Wallace et al., 1982) and reading achievement (Nickel et al., 1982; Wallace, Escalona, McCarton-Daum, & Vaughan, 1982). None of these reports have included comparisons between medical risk subgroups within a low birthweight sample, although there have been reports of a high incidence of language delays (Hirata et al., 1983; Hunt, 1981; Ross, Lipper & Auld, 1985) and poor reading achievement (Steiner, Sanders, Phillips, & Maddock, 1980; Vohr & Garcia-Coll, 1985) despite normal IQ.

Among studies that have included a normal birthweight comparison group, there have also been fairly consistent reports of mean scores on the Wechsler Verbal IQ (Astbury et al., 1990; Marlow et al., 1989; Michelsson et al., 1984; Noble-Jamieson, Lukeman, Silverman, & Davies, 1982), the McCarthy Verbal Scale score (Field et al., 1983; Jacob et al., 1984; Siegel, 1982b) and vocabulary tests (Klein, 1988; Lloyd, 1984; Siegel, 1983) that are within the normal range. There have been inconsistent findings concerning group differences in language outcome, with some reports of no significant differences between the mean language scores of low birthweight children and a normal birthweight comparison group (Holmes et al., 1988; Jacob et al.,1984; Klein, 1988; Lloyd, 1984; Siegel, 1982, 1983), and some reports of significantly lower mean scores on measures of early childhood language outcome for low birthweight children (Klein, Hack, Gallagher, & Fanaroff, 1985; Largo, Molinari, Comenale, Weber, & Duc, 1986; Marlow et al., 1989; Michelsson et al., 1984; Portnoy, Callias, Wolke, & Gamsu, 1988; Vohr, Garcia-Coll, & Oh, 1989).

In summary, many low birthweight children perform within the normal range on measures of language outcome, although there may be an increased risk for language problems. There have been inconsistent reports of differences in language outcome between low birthweight and normal birthweight children, and little information concerning differences in language outcome between medical risk subgroups within a low birthweight sample.

Motor outcome. There has been considerable research on motor development among low birthweight children, due to risks to the central nervous system thought to be associated with neonatal immaturity and illness and to an interest in the relation between visual-motor problems during early childhood and problems in school achievement (Horn & O'Donnell, 1984; Simner, 1983). Visual-motor skills have been assessed with paper and pencil tests such as the

Developmental Test of Visual Motor Integration (Beery & Buktenica, 1982), in which the child copies increasingly complex geometric designs. Other aspects of motor skills have been assessed with summary measures such as the Motor Scale of the McCarthy Scales. This scale includes arm coordination (catching and throwing) and leg coordination (walking and balancing) activities as well as drawing items.

Among studies of low birthweight samples, there have been several reports of mean scores within the normal range on measures of visual-motor integration (Nickel et al., 1982; Rose & Wallace, 1985b; Saigal et al., 1990; Wallace et al., 1982) and on summary measures of motor skills (Crowe, Deitz, Bennet, & Tekolste, 1988; Saigal et al., 1990; Vohr & Garcia-Coll, 1985). There have also been reports of a high percentage of delays (Ford et al., 1989; Hirata et al, 1983; Hunt et al., 1982; Nickel et al., 1982; Vohr & Garcia-Coll, 1985) and significantly lower mean scores (Crowe et al., 1988) among the most immature low birthweight subgroups.

Among studies that have included a normal birthweight comparison group, there have also been reports of mean scores within the normal range on motor outcome measures (Field et al., 1983; Siegel, 1982). There have also been consistent findings of significantly lower scores on measures of visual-motor integration (Klein, 1988; McDonald et al., 1989; Nickel et al., 1982; Siegel, 1983) and on summary measures of motor outcome (Field et al., 1983;

Forslund, & Bjerre, 1989; Michelsson et al., 1984; Nickel et al., 1982; Siegel, 1982) among low birthweight children, despite no group differences on IQ measures.

In summary, descriptions of early childhood motor outcome have been fairly consistent. Although there has been some evidence that the visual-motor and gross motor scores of many low birthweight children are within the normal range, there are several reports of motor deficits despite normal IQ and of significantly poorer motor skills relative to a normal birthweight comparison group. These are often reports of the most immature subgroups within the low birthweight population. These results suggest that medical risk may contribute to variability in motor outcome within a low birthweight sample.

Attention. Attention represents an aspect of functioning that may have implications for other cognitive outcomes. An extensive body of research on attention has existed in the educational and clinical literature. Inattention, impulsivity and hyperactivity have been related to a variety of cognitive, learning and behaviour problems (Barkley, 1991; Douglas & Peters, 1979; Horn & Packard, 1985; Krupski, 1986; Simner, 1983).

Although this literature has been characterized by considerable discussion concerning the definition of attention deficit (Barkley, 1991; Douglas & Peters, 1979; Krupski, 1986; Whalen, 1989), there has been some consensus concerning the multiple aspects of attention problems --

inattention, impulsivity and hyperactivity (Barkley, 1991). Children with attention problems demonstrate difficulties in sustaining attention to a task and in social settings, and in inhibiting impulsive, premature and inaccurate responses during tasks or in social situations. Cognitive tasks that require sustained, organized, and self-directed behaviour appear to be particularly sensitive to these differences between children (Douglas & Peters, 1979). In addition, hyperactivity, or excessive and inappropriate motor activity, is often associated with problems of inattention and impulsivity.

However, attention outcome has received relatively little systematic consideration in research on the consequences of low birthweight, despite suggestions of a "behavior syndrome" (Shirley, 1939, p. 116), "concentration and attention difficulties" (Benton, 1940, p. 743) and an increased incidence of "hyperactive syndrome" (Caputo & Mandell, 1970, p. 375) in earlier research. The existing low birthweight research literature has used a wide variety of individual measures of attention. Task measures evident in the educational and clinical literature have been infrequent. Measures that have been used include ratings of child behaviour during testing or in school, scores obtained from parent questionnaires, or scores on dimensions of child temperament that are relevant to attention. The use of multiple measures of attention has been rare, despite suggestions that the multi-dimensional assessment of attention represents a useful direction (Krupski, 1986).

Task measures of sustained attention have been absent in the low birthweight literature, despite their utility in differentiating children with attention problems (Douglas & Peters, 1979; Krupski, 1986). Task measures of impulsivity, such as the Matching Familiar Figures Test (Kagan, Rosman, Day, Albert, & Phillips, 1964), have been used in developmental and educational research, but have not been evident in the low birthweight research, although one study has included a task measure that is similar to the MFFT (Siegel, 1983). Siegel (1983) compared her sample of very low birthweight children to a normal birthweight comparison group on a recognition-discrimination task, used in educational research as a measure of perceptual and attention skills (Satz & Friel, 1973). During this task, the child was presented with a target stimulus and asked to select a match from among four alternatives. Siegel reported that very low birthweight children had a significantly lower number of correct matches.

Behaviour ratings have been another method of assessing attention outcome, and, among studies using these measures, there have been reports of a high proportion of attention problems among very low birthweight samples (Astbury et al., 1987; Hunt, 1982; Ross et al., 1985; Steiner et al., 1980). For example, Astbury et al. (1987) used ratings of inattention, impulsivity, and hyperactivity during testing in a study of very low birthweight children at 5 years of age and reported that 33% of the sample demonstrated an attention deficit. Among studies that have included a normal birthweight comparison group, there have been inconsistent reports of group differences on behaviour rating measures of inattention and impulsivity (Jacob et al., 1984; Parkinson, Wallis, & Harvey, 1981). For example, in a study of 3-year old low birthweight children, Jacob et al. (1984) derived measures of task persistence and impulsivity from ratings of behaviour during problem solving tasks, and reported that there were no differences on these measures between low birthweight children and a comparison group. However, Parkinson et al. (1981) reported that low birthweight children obtained significantly lower teacher ratings of concentration than a comparison group.

A few studies have used child behaviour questionnaires as a measure of attention during early childhood (Klein, 1988; Sigman, Cohen, Beckwith, & Topinka, 1987; Szatmari, Saigal, Rosenbaum, Campbell, & King, 1990). For example, Klein (1988) used a teacher-completed child behaviour questionnaire in her study of a sample of 5-year-old very low birthweight children. The very low birthweight children were reported to have significantly more problems in attention to cognitive tasks than a normal birthweight comparison group, though they were not significantly more impulsive or hyperactive. Szatmari et al. (1990) used scores on a child behaviour checklist as a basis for a diagnosis of Attention Deficit Disorder in their study of a sample of 5-year-old extremely low birthweight children. They observed that the rate of attention problems among these children was significantly greater than the rate among a normal birthweight comparison group.

Attention has also been assessed with temperament measures of distractibility, persistence, sensory threshold, and activity level. All of these studies have included a normal birthweight comparison group, and have included reports of greater distractibility, lower attention span (Field et al., 1983; Hertzig & Mittleman, 1984), and higher sensory threshold (Hertzig & Mittleman, 1984; Parkinson, Scrivener, Graves, Bunton, & Harvey, 1986) among low birthweight samples. These difference in distractibility and threshold have been interpreted as indicating inadequate or delayed responses to sensory stimuli, behavioural dimensions that are related to inattention and impulsivity. Reports of activity level have been inconsistent. Field et al. (1983) reported that their sample of 5-year-old low birthweight children obtained a significantly higher score on activity level on a temperament inventory, whereas there have also been reports of equivalent (Hertzig & Mittleman, 1984) or lower (Parkinson et al., 1981) scores among low birthweight children on such measures.

In summary, a wide variety of single measures of attention during early childhood have been used in the low birthweight research. Reports of this research have been inconsistent and there has been little information concerning subgroup differences within a low birthweight sample. Reports based on summary rating or questionnaire measures have suggested a greater risk for attention problems among low birthweight children. Reports based on rating, questionnaire or temperament measures of inattention have been inconsistent, as have those based on a variety of measures of impulsivity. Finally, reports of hyperactivity have been based primarily on questionnaire or temperament measures and have been quite inconsistent.

This pattern of discrepant findings may be attributable in part to the use of single, possibly unreliable measures. Furthermore, although multiple aspects of attention problems in young children -- inattention, impulsivity and hyperactivity -- have been acknowledged in the educational and clinical literature (Barkley, 1991; Douglas & Peters, 1979), these have not been systematically documented in the low birthweight research. Conclusions concerning the importance of medical risk to attention outcome have been complicated by these methodological factors.

Implications for the current study.

Several general trends have been discerned in this recent literature. First, the global cognitive development of many low birthweight infants has been reported to be within the normal range and close to that of normal birthweight children (Cohen, 1986; Hoy et al., 1988; Kopp, 1983). Therefore, the utility of global outcome measures for describing the consequences of low birthweight may be limited. Second, low birthweight children have been reported to be at an increased risk for problems in specific aspects of functioning such as language, motor skills, and attention (Cohen, Parmalee, Beckwith, & Sigman, 1986; Hunt et al., 1982). However, information concerning attention has been limited. Finally, birthweight per se has not been clearly related to childhood outcomes. There have been inconsistent reports of differences between birthweight subgroups within a low birthweight sample and between low birthweight and demographically-matched normal birthweight comparison groups. These discrepant findings may be attributable to methodological factors and the heterogeneity of the low birthweight population. In addition, the use of birthweight alone as a measure of neonatal status results in a loss of information concerning the impact of other aspects of medical risk - related measures of immaturity and neonatal illness. Furthermore, these findings also suggest that factors other than medical risk may be important to an understanding of the consequences of low birthweight for childhood development and that the role of medical risk may differ for different outcomes.

Research describing outcomes among low birthweight children had several implications for the design of the current study and the choice of measures. Measures of global cognitive outcome and specific aspects of cognitive functioning were chosen, as global measures alone may be of limited utility in an understanding of the consequences of low birthweight. Furthermore, attention outcome was assessed by way of multiple measures -- task performance, behaviour ratings, and parent reports -- in order to obtain a more reliable and meaningful assessment.

Hypotheses

On the basis of previous research, it was expected that the mean scores on measures of global cognitive and language outcome would be within the normal range and that there would be no differences between medical risk subgroups within the sample. It was also expected that mean scores on measures of motor outcome would be within the normal range, but that there would be significant differences between medical risk subgroups within the sample on these outcome measures. Existing research evidence concerning attention outcome is sparse and inconsistent, but suggests that there might be differences between medical risk subgroups on measures of inattention, impulsivity and hyperactivity.

# METHOD

## Subjects

Potential subjects for the current study were a sample of low birthweight children and their parents. When the children were infants, they had participated in a prospective longitudinal study of factors that contribute to optimal developmental outcome at 12 months of age (Pederson, Evans, Chance, Bento, & Fox, 1988).

Potential subjects for the infant study were 159 infants with birthweights equal to or less than 2500 g. They were born between August 1982 and August 1984 and admitted to the neonatal intensive care units (NICU) at two hospitals in London, Ontario, Canada. None of the infants had gross neurological or physical anomalies at birth; all of the mothers spoke English; and all families lived within 100 km of either hospital. The sampling procedure specified that physicians at the two hospitals were responsible for contacting eligible families and referring the family names to the research coordinator of the infant study, who then contacted the families directly.

Admission records were available from one of these hospitals, St. Joseph's Hospital, and indicated that there were a total of 713 admissions to the NICU during the recruitment period. Of these, 283 infants were admitted whose families lived within the designated geographical area. Of the 159 children referred by physicians for the infant study, 97 (61%) were admitted to the NICU at St.

Joseph's, and represented 34% of infants admitted to St. Joseph's from families within the designated geographical area during the recruitment period.

The mothers of eight eligible infants declined to participate in the infant study. Nineteen infants could not be assessed at 12 months of age. Eight of these infants had moved or could not be located; eleven had either visual or severe motor impairments. Potential subjects for the current study, therefore, were the 132 children who were tested at 12 months during the infant study. Of these 132 children, 90 (68%) were admitted to the NICU at St. Joseph's, and represented 32% of infants admitted to that hospital from families within the designated geographical area during the recruitment period.

Consent to contact the families for the purpose of a childhood follow-up study had been obtained during the last contact of the infant study, when the children were 12 months old. One hundred per cent of the parents involved in the infant study had given their consent for future contact.

When the child was 5 years, 6 months old, the research coordinator of the infant study telephoned the parents of potential subjects and invited them to participate in the current study. The examiner subsequently telephoned those parents who agreed to participate, briefly described the study procedure, and scheduled an appointment for a home visit.

Ninety children who participated in the infant study participated in the current study. Of these 90 children, 57 (63%) were admitted to the NICU at St. Joseph's, and represented 20% of infants admitted to that hospital from families within the designated geographical area during the recruitment period of the infant study. Forty-two children who participated in the infant study did not participate in the current study. The parents of one child declined; one child had died. Six children did not participate because their parents cancelled appointments without indicating an interest in rescheduling, and fourteen children did not participate because they had moved or could not be located. Twenty children were not contacted for the follow-up study because they were not yet 5 years, 6 months old when the data gathering ended for this study.

The 90 children (51 girls and 39 boys) who participated in the current study were compared to the 42 children who did not on data that had been collected during the infant study. These data for participants and non-participants are presented in Table 1. During the neonatal period, the infant's medical history and family demographic characteristics had been recorded. Birthweight, gestational age, number of days in hospital, a summary measure of the severity of the infant's morbidity or illness in hospital (developed by Minde, Whitelaw, & Brown, 1983), and severity of respiratory distress syndrome (RDS) had been recorded. The morbidity scale consists of the 20 most common medical

Table 1

Means and standard deviations of infant measures for participants (n=90) and non-participants (n=42)

| | | Group | | | |
|---|---|---|---|---|---|
| | | Participants | Non Participants | *t* | (df) |
| **Medical risk measures** | | | | | |
| Birthweight | *M* | 1757.5 | 1526.3 | 2.43* | (130) |
| | *SD* | 515.1 | 496.1 | | |
| Gestational age | *M* | 32.7 | 31.9 | 1.17 | (130) |
| | *SD* | 3.5 | 3.7 | | |
| Morbidity | *M* | 52.2 | 70.0 | - .97 | (130) |
| | *SD* | 92.5 | 109.1 | | |
| Days in hospital | *M* | 37.9 | 52.3 | -2.03 | (130) |
| | *SD* | 30.1 | 50.8 | | |
| RDS severity | *M* | 6.9 | 8.7 | -1.05 | (130) |
| | *SD* | 8.7 | 9.4 | | |
| **Demographic measures** | | | | | |
| Maternal age | *M* | 26.0 | 25.3 | .85 | (130) |
| | *SD* | 4.0 | 5.0 | | |

Table 1, cont'd.

Means and standard deviations of infant measures for participants (n=90) and non-participants (n=42)

| | | Group | | |
|---|---|---|---|---|
| | | Participants | Non Participants | t (df) |
| Maternal education | M | 12.1 | 11.9 | .45 (130) |
| | SD | 1.9 | 2.2 | |
| Paternal education | | n=90 | n=41 | |
| | M | 12.5 | 12.3 | .40 (129) |
| | SD | 2.6 | 2.9 | |
| Occupational status[1] | M | 37.1 | 36.1 | .41 (130) |
| | SD | 13.1 | 12.9 | |
| Environmental measures | | | | |
| 7 month HOME | M | 5.4 | 4.6 | 2.32 (130) |
| | SD | 1.9 | 2.1 | |
| 12 month HOME | | n=88 | n=38 | |
| | M | 5.9 | 5.0 | 2.31 (124) |
| | SD | 1.9 | 2.4 | |

Table 1, cont'd.

*Means and standard deviations of infant measures for participants (n=90) and non-participants (n=42)*

| | | Group | | | |
|---|---|---|---|---|---|
| | | Participants | Non Participants | *t* | (df) |
| 7 month | | | | | |
| Sensitivity | *M* | 5.4 | 5.1 | .78 | (130) |
| | *SD* | 1.9 | 2.2 | | |
| 12 month | | | | | |
| Sensitivity | | *n*=88 | *n*=38 | | |
| | *M* | 5.8 | 4.9 | 2.31 | (124) |
| | *SD* | 1.9 | 2.3 | | |
| Developmental measures | | | | | |
| Uncorrected MDI | *M* | 104.1 | 95.9 | 2.52* | (130) |
| | *SD* | 17.3 | 17.6 | | |
| Uncorrected PDI | *M* | 87.5 | 80.8 | 2.05 | (130) |
| | *SD* | 16.9 | 18.3 | | |
| Corrected MDI | *M* | 120.9 | 113.8 | 2.46* | (130) |
| | *SD* | 15.6 | 14.5 | | |
| Corrected PDI | *M* | 97.5 | 90.7 | 1.93 | (130) |
| | *SD* | 17.5 | 21.3 | | |

*= $p < .01$. [1] Assessed with the Blishen Index, a measure based upon Canadian census data (Blishen & McRoberts, 1976).

conditions experienced by preterm infants. Each medical condition was rated daily on a scale of 0-3 that is based on objective criteria. Daily scores were summed in order to provide a total morbidity score. RDS, or respiratory distress syndrome, is among the most common of these medical conditions. Severity of RDS was derived by summing the RDS scores from the morbidity scale over the first 8 days in hospital. The daily scores ranged from 0 (no RDS), 1 (infant on low flow oxygen), 2 (infant required continuous positive airway pressure), to 3 (infant required ventilation). Maternal age, parental education, and a measure of occupational status based on Canadian census data (Blishen & McRoberts, 1976) had also been obtained. At 7 and 12 months of age (corrected for weeks of prematurity), home visits had provided ratings of maternal sensitivity (based upon procedures developed by Ainsworth, Bell, & Stayton, 1974) and a measure of the quality of stimulation in the child's physical and social environment (obtained from the HOME Inventory developed by Bradley & Caldwell, 1980). The Bayley Scales of Mental and Motor Development (Bayley, 1969) had been administered as part of the 12 month visit. The Bayley Scales provided two measures -- the Mental Development Index (MDI) and the Psychomotor Development Index (PDI). The test was administered at 12 months corrected age; both corrected and uncorrected scores are reported.

T-tests were used to compare the 90 children who participated in the current study to the 42 children who did not on the basis of these measures of medical risk, infant environment, and infant status. In order to avoid being overly conservative in these multiple comparisons, that addressed the issue of sample attrition, a Type I error rate of .01 per comparison was set. Non-participants had significantly lower scores on measures of birthweight and infant mental development, and tended to have lower mean scores on measures of the infant environment and infant psychomotor development. The test scores appear to have been influenced by a few extreme cases in the non-participant group. For example, 12 (29%) of the non-participants had uncorrected Bayley MDI scores that were less than 84 (1 standard deviation below the sample mean) and 3 of these children (7% of the non-participants) had scores less than 68 (2 standard deviations below the sample mean). Six (50%) of the children with MDI scores less than 84 did not participate because they had moved or could not be located; the parents of one of these children declined to participate; and 5 (42%) of these children had not yet been contacted for the current study.

The 90 participants included 51 (56.7%) first born children and 76 (84.4%) singletons. The participants were characterized by considerable variability on several measures of immaturity and illness. At birth, 64 (71.1%) of the children weighed between 2501 g and 1500 g; 18 children

(20%) weighed between less than 1500 g and more than 1000 g; and eight children (8.9%) weighed less than 1000 g. Twenty-seven children (30%) had been classified as small-for-gestational-age (SGA) at birth. During hospitalization in the NICU, 51 (67.8%) of the children had experienced RDS; 11 (12.4%) of the children had experienced severe chronic lung disease. Ten children (11.2%) had experienced an intraventricular hemorrhage of Grade 2 or 3 level.

Each participant was assessed during two home visits of approximately two hours each. Visit 1 was, when possible, scheduled when the child was approximately 5 years, 6 months old. Visit 2 was, when possible, scheduled within one month after Visit 1. Three children did not participate in Visit 2 and, therefore, data on these children are incomplete. The mother of one child declined to continue to participate following Visit 1; the family of one child moved and Visit 2 was postponed; the mother of another child began a course of study and Visit 2 was cancelled. Mean age at the time of Visit 1 ($n$=90) was 68.94 months ($s$=2.83 months). Mean age at the time of Visit 2 ($n$=87) was 70.37 months ($s$=3.11 months).

Each visit was conducted by a female examiner in the child's home at a time when at least one parent would be present and when the child would be available for approximately 45 minutes of testing. Apart from her knowledge that all children were born at a low birthweight, the examiner was blind to the child's neonatal medical history, infant environment, and infant developmental status.

The childhood demographic characteristics of the 90 children and families who participated in the current study are presented in Table 2. The children were generally from well educated backgrounds; the mean year of education for mothers and fathers was approximately 12-13 years. The measure of occupational status, derived from Canadian census data (Blishen & McRoberts, 1976) indicated that the occupational level of 11% of the fathers was unskilled labor, 69% were in semiskilled occupations, and 20% were in skilled trades or professions. Mean family income was approximately $37,500 Canadian, although income ranged, according to parent reports, from $5,000 to over $50,000.

## Materials and Procedure

### Overview

The procedure consisted of two home visits of approximately two hours each. Visit 1 consisted of four parts. First, the examiner introduced herself, provided a letter of information concerning the study, and obtained parental consent. The letter of information and the consent form are presented in Appendix I. Second, the examiner administered a standardized measure of child cognitive and motor development and rated the child's behaviour during testing on inattention, impulsivity and hyperactivity. Next, the examiner conducted the parental interview to obtain information about the demographic characteristics of the

Table 2

Means and standard deviations of child demographic measures (n=90)

| | M | SD |
|---|---|---|
| Maternal age | 31.6 | 4.0 |
| Maternal education (years) | 12.3 | 1.9 |
| Paternal education (years) | 12.7 | 2.6 |
| Occupational status | 42.3 | 14.1 |
| Income ($CDN) | 37,500 | 8,500 |

family and the quality of the child environment. Finally, the examiner presented three questionnaires concerning child behaviour relevant to attentional differences among children, child behaviour problems, and parenting stress and asked the child's mother to complete them prior to Visit 2.

Visit 2 consisted of three parts. First, the examiner administered standardized measures of child visual-motor skills and vocabulary, and two attention tasks. The same order of presentation of these tests was used for all children. Following the first attention task, the examiner rated the child's behaviour during testing on inattention, impulsivity and hyperactivity. Next, the examiner provided the parent with feedback about the child's performance on the cognitive, motor, and attention measures. The examiner then administered a standardized measure of vocabulary to the child's mother to obtain information about the quality of language in the child environment, and completed the parental interview. Finally, the examiner collected the completed questionnaires, obtained permission for future contact, and thanked the children and their families for participating in the study.

Child cognitive and motor measures.

McCarthy Scales of Children's Abilities. The McCarthy Scales of Children's Abilities (McCarthy, 1972) were used because, unlike the Stanford-Binet or the Wechlser intelligence tests, they provide measures of four specific aspects of cognitive functioning, and a measure of motor skills, as well as a global cognitive measure. This characteristic of the McCarthy met the need to obtain information about specific childhood cognitive and motor outcomes. The McCarthy Scales (MSCA), designed for children between the ages of 2 1/2 and 8 1/2 years of age, consist of 18 subtests that include a variety of tasks. The subtests are grouped to provide a General Cognitive Index (GCI) as well as scores on Verbal, Perceptual-Performance, Quantitative, Memory and Motor Scales. The GCI has a mean of 100 and a standard deviation of 16. Each of the scale scores has a mean of 50 and a standard deviation of 10.

The psychometric characteristics of the MSCA are reported in detail in the test manual and are considered to be quite satisfactory (Sattler, 1982). The test was standardized on a sample of approximately 1,000 normally developing children in the United States; the sample was stratified by race, region and father's occupational status. One-month test-retest reliability was obtained from a stratified sample of 125 children of three age groups; the mean test-retest reliability coefficient was .90 for the GCI and ranged from .69 to .80 for the other scales. Internal consistency reliability was obtained from children of 10 age groups between 2 1/2 and 8 1/2 years of age; the mean reliability coefficient was .93 for the GCI; and ranged from .79 to .88 for the other scales (McCarthy, 1972).

Validity research has been extensive. Factor analytic studies have supported the construct validity of the

McCarthy for normal and exceptional children (Kaufman & Kaufman, 1977; Keith & Bolen, 1980; Naglieri, Kaufman, & Harrison, 1981), although support for the GCI, Verbal, Perceptual-Performance, and Motor scales has been stronger than for the Memory and Quantitative scales. Research on the concurrent validity of the MSCA has focused on the relationship between the GCI and IQ scores. The GCI correlates significantly with full scale WPPSI (.71) and Stanford-Binet (.81) IQ scores (McCarthy, 1972). Validity research has also demonstrated that the predictive validity of the GCI, Quantitative and Perceptual-Performance scales for Grade 1 achievement is satisfactory and similar to the Stanford Binet and the WPPSI (McCarthy, 1972).

The MSCA were administered according to standardized procedures described in the test manual. It was the only test administered during Visit 1. Eighty-eight children completed the MSCA. Two children did not complete this measure. One child was extremely uncooperative during testing. Time constraints prevented another child from completing this measure, although all Motor scale items were completed.

Developmental Test of Visual Motor Integration. The Developmental Test of Visual Motor Integration (Beery & Buktenica, 1982) was used as a measure of visual-motor skills that could be aggregated with the McCarthy Motor scale score to provide a summary measure of motor outcome. This test was designed to evaluate visual perception and motor coordination in children between the ages of 2 and 15 years. During this paper and pencil test, the child copies a series of individual geometric designs of increasing complexity. The child's raw score can be transformed into a standard score and into an age equivalent.

The psychometric properties of the Developmental Test of Visual Motor Integration (VMI) are superior to other measures of visual-motor skills (Salvia & Ysseldyke, 1985). The test was standardized on a sample of approximately 1,000 children. Test-retest reliability coefficients, reported in the manual, ranged from .80 to .90. Inter-rater reliability was reported as .96.

The VMI was administered according to standardized procedures described in the test manual. It was the first test administered during Visit 2 and was followed by the Peabody Picture Vocabulary Test-Revised. Eighty five children completed the VMI. Three children did not participate in Visit 2. One child had very recently been tested with this measure, and time constraints prevented another child from completing this measure.

Peabody Picture Vocabulary Test-Revised. The Peabody Picture Vocabulary Test-Revised, Form L (Dunn & Dunn, 1981) was used as a measure of child receptive vocabulary. For each test item, the child was presented with four pictures and must point to the picture that represents the stimulus word read by the examiner. The child's raw score on the

PPVT-R was transformed into a standard score. The standard score has a mean of 100 and a standard deviation of 15.

The psychometric properties of the PPVT-R are superior to those of most other picture vocabulary tests (Salvia & Ysseldyke, 1985). The test was standardized on a sample of over 4,000 normally developing children between 2 1/2 and 18 years of age and on approximately 800 adults. Both samples were stratified by sex, race, region and occupational status. Test-retest reliability coefficients for PPVT-R standard scores range from .71 to .89. Internal consistency reliabilty coefficients range from .61 to .88. Validity research on this recent revision of the Peabody has been limited thus far.

The PPVT-R was administered to the child according to standard procedures provided in the test manual. It was the second test administered during Visit 2 and was followed by the attention task measures. Eight-six children completed the PPVT-R. Three children did not participate in Visit 2, and another child had recently been assessed with this measure.

<u>Attention task and behaviour rating measures</u>.

<u>Vigilance Tasks</u>. Two related visual vigilance tasks were used to provide measures of sustained attention and impulsivity. These tasks were based on the Continuous Performance Task (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), and modifications of the task used in research

on learning-disabled and hyperactive children (Douglas & Peters, 1979; Krupski, 1986; Swanson, 1981, 1983).

The vigilance tasks were presented on a Tandy 102 portable computer. During each task, twelve letters (R,G,K,Z,V,S,A,X,D,C,V, and W) were randomly ordered for a total of 150 individual letter presentations. The letters were .5 cm high, were displayed in the center of the 5.5 cm x 19.5 cm screen and presented at a rate of 1 second each, with a 1 second interval between letter presentations. A removable mask for the keyboard was constructed to mask all keys but the space bar at the bottom of the keyboard.

The letter X was designated as the target letter. During the first vigilance task, the X task, the child was asked to attend through a 5-minute task period and press the space bar each time an X was presented. Out of 150 letter presentations, there were 30 X's presented. During the second, more complex vigilance task, the AX task, the child was asked to attend through a 5-minute task period and press the bar each time an X immediately followed an A. Out of 150 letter presentations, there were 30 A's followed by X's. The number of correct responses (hits), a measure of sustained attention, and the number of incorrect responses (false alarms), a measure of impulsive responses, were recorded and tallied by the computer during the duration of each task.

The psychometric properties of similar vigilance tasks have been reported in the developmental and educational literature. Rosvold et al. (1956) reported on the reliability of tasks that were similar to those used in the present study. They studied the performance of three clinical groups of subjects. The reliability data were obtained from a group of institutionalized retarded adults. Test-retest reliability for the number of correct responses (hits) by a non-brain damaged subgroup was .88 for the X task and .74 for the AX task. Internal consistency reliabilities coefficients were .88 for the X task and .86 for the AX task. Sykes, Douglas, and Morgenstern (1973) reported the test-retest reliability for four attention tasks, including a vigilance task, administered to 20 eight-year-old hyperactive children of normal intelligence. The reliability coefficients for individual tasks were not reported; they ranged from .50 to .87.

The validity of the vigilance task has been considered in research on children with learning difficulties. In a review of this literature, Krupski (1986) reported that poorer performance on the vigilance task -- lower hit rates (difficulty sustaining attention) and higher false alarm rates (difficulty inhibiting impulsive responses) -- have been associated with hyperactivity and learning disabilities in young children.

The vigilance task games were administered according to instructions developed for the purpose of this study and based on those reported by Rosvold et al. (1956) and Swanson (1981). First, the examiner presented the computer to the child and provided a general introduction to the vigilance task games. "Now we are going to play some letter games. You will play the letter games on this little computer that I have. You will see the letters on this screen here." Next a series of pretests was administered. An outline of the procedure for the vigilance tasks is presented in Figure 1.

Naming Pretest. The purpose of the naming pretest was to test the child's knowledge of the target letter, X, and the letter A.

> You will see some letters one at a time on the screen. First, your job is to say the names of some letters. It's OK if you don't know the name of a letter. Just tell me what you think the name is. Try to sit so that you can see the letters clearly. Are you ready?

The examiner pressed the space bar in order to present each of the 12 individual letter trials. Each letter was displayed in the center of the screen. During each letter trial the examiner asked "What letter is this one?" and recorded the child's response.

X Task: Discrimination Pretest. Children who did not correctly name the X during the Naming Pretest were presented with the X Discrimination Pretest. The examiner explained "Now your job is to point to the X" and pressed the space bar in order to present the first trial, a match-to-target trial. The screen display for this trial consisted of the letter X at the center top of the screen

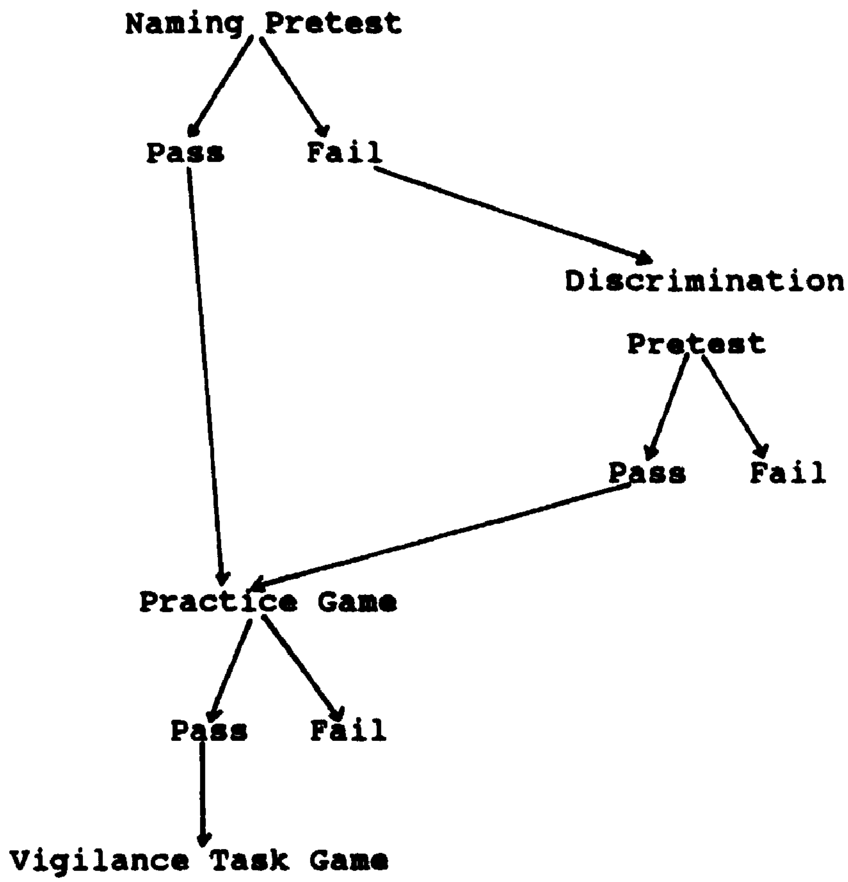


Figure 1. Outline of vigilance task game procedure

and all 12 letters in a row at the bottom of the screen. Pointing to the X at the top of the screen, the examiner said "Here is an X". Pointing to the row of letters at the bottom of the screen, the examiner said "Point to the X in this row of letters". Following the first trial, there were three more trials. The screen display for each of these trials consisted only of a row of all 12 letters. The randomly determined order of letters was different for each trial. During each trial, the examiner said "Now point to the X" and recorded the child's response. Children who did not correctly discriminate the X on these three trials of were not presented with the X Vigilance Task. Three children did not pass either the Naming or the X Discrimination Pretests and, therefore, did not complete the vigilance tasks. One child was extremely noncompliant during testing and was not presented with any of the vigilance task activities. Vigilance task data were not available for three children who did not participate in Visit 2.

X Task: Practice Pretest. Children who correctly named the X during the Naming Pretest or who correctly discriminated the X on three trials of the X Discrimination Pretest were presented with the X Task Practice Pretest. The purpose of the X Practice Pretest was to familiarize the child with the bar pressing and insure that the child understood the instructions.

> Now you are going to play a letter game. It is called the Get the X game. When the computer starts, you will

see letters one at a time. Your job is to press this bar every time you see an X. That's why the game is called the Get the X game. Don't press the bar for any other letter but always press it every time you see an X. When you see an X, press the bar down on the X and let it up again. Sit so that you can see the letters clearly. Watch carefully and pay attention. Remember, press the bar every time you see an X, but not for any other letter. Just press the bar down on the X and let it up again. Let's practice. Ready? Get the X.

The examiner pressed the space bar in order to begin the X Practice Pretest. Out of 25 letter presentations there were 4 X's (16%) presented. At the end of the X Practice Pretest, the examiner recorded the number of correct and incorrect responses. Practices were repeated up to a total of three pretests until the child correctly detected 50% of the X's presented during one pretest. Children who did not meet this criterion were not presented with the X Vigilance Task. Eighty-three children met the pretest and practice criteria and completed the X Task.

X Task. The examiner then presented the X Task.

That was fine. You watched carefully and pressed the bar every time you saw an X. You remembered to get the X. Now let's play this game some more. This time the game will take longer to play. This time you will see a lot of letters. Remember, when the computer starts you will see letters appearing one at a time. Your job is to press this bar every time you see an X. Don't press it for any other letter and always press it when you see an X. Remember, when you see an X, just press the bar down on the X and let it up again. Watch carefully and pay attention. Ready? Get the X.

The examiner pressed the space bar in order to begin the X Task. During the 5-minute task period, all children received the prompt "Watch carefully and pay attention. Get the X" at 1-minute intervals. If the game was interrupted, the examiner interrupted the presentation of letters and recorded the number of correct and incorrect responses. The game was resumed as soon as possible. If the child refused to complete the game, the number of correct and incorrect responses up to the point of refusal was the basis for the child's score on the X Task. Following the completion of the X Task, the examiner recorded the number of correct and incorrect responses.

The examiner then informed the child that there would be a short break and that there was another letter game she wanted the child to play. Following a 2-minute break, the examiner introduced the AX Task with discrimination and practice pretests.

AX Task: Discrimination Pretest. Children who did not correctly name the A during the Naming Pretest were presented with the A Discrimination Pretest. The examiner explained "Now your job is to point to the A and point to the X" and pressed the space bar in order to present the first trial, a match-to-target trial. The screen display for the first trial consisted of the letter A at the center top of the screen and all 12 stimulus letters in a row at the bottom of the screen. Pointing to the A at the top of the screen, the examiner said "Here is an A". Pointing to the row of letters at the bottom of the screen, the examiner said "Point to the A in this row of letters. Now point to the X ". Following the first trial, there were three more trials. The screen display for each trial consisted only of a row of all 12 letters. The randomly determined order of letters was different for each trial and randomly determined. During each trial, the examiner said "Now point to the A. Now point to the X" and recorded the child's response. Children who did not correctly discriminate the A on the last three trials of the A Discrimination Pretest were not presented with the AX Task. Fifteen children refused to participate in the AX Task activities; three children did not pass the AX Discrimination Pretest. Therefore, 18 children did not complete the AX vigilance tasks practice pretest.

<u>AX Task: Practice Pretest</u>. Children who correctly named the A during the Naming Pretest or correctly discriminated the A on three trials of the A Discrimination Pretest were presented with the AX Practice Pretest. The purpose of the practice pretest was to insure that the child understood the instructions.

Now you are going to play a letter game. It is called Get the X After the A. When the computer starts, you will see letters one at a time. Your job in this game is again to press this bar every time you see an X, but only if the X comes right after an A. That is when you see an A and then an X press the bar on the X. Don't press the bar for any other letter that comes after an A except X, and always press it then. When you see an X that comes after an A, just press the bar down on the X and let it up again. Remember now, when you see the letter A, get set; if an X comes right after it, press the bar. Let's practice. Ready? Get the X that comes after the A.

The examiner pressed the space bar in order to begin the AX Practice Pretest. Out of 25 letter presentations, there were 4 A's followed by X's (16%) presented. At the end of the practice pretest, the examiner recorded the number of correct and incorrect responses. Practices were repeated up to a total of three pretests until the child correctly detected 50% of the X's that followed A's presented during one pretest. Children who did not meet this criterion or refused to continue were not presented with the AX task. Five children refused to continue. Therefore, 59 children met all the pretest criteria and completed the AX Task.

AX Task. The examiner then presented the AX Task.

That was fine. You watched carefully and pressed the bar every time you saw an X come right after an A. Now

> let's play this game some more. This time the game will take longer to play. This time you will see a lot of letters. Remember, your job is to again press this bar every time you see an X, but only if the X comes right after an A. When you see an A and then an X, press the bar on the X. Remember when you see an A and then an X, just press the bar down on the X and let it up again. Remember when you see the letter A, get set; if an X comes right after it, press the bar. Watch carefully and pay attention. Ready?

The examiner pressed the space bar in order to begin the AX Task. During the 5-minute task, all children received the prompt "Watch carefully and pay attention. Get the X after the A" at 1-minute intervals. If the game was interrupted, the examiner interrupted the presentation of letter stimuli and recorded the number of correct and incorrect responses. The game was resumed as soon as possible. If the child refused to complete the task, the number of correct and incorrect responses up to the point of refusal was the basis for the child's score on the AX Task. The examiner displayed and recorded the number of correct and incorrect responses.

Following the completion of the vigilance task(s) the examiner praised the child and told the child how many X's he/she had detected during the tasks. Eighty-three children met the pretest criteria and played the X Task. Fifty-nine of these children met the pretest criteria and also played the AX Task.

Matching Familiar Figures Test. The Matching Familiar Figures Test, Form F (Kagan et al., 1964) was used to provide two additional measures of impulsivity. The Matching Familiar Figures Test (MFFT) was developed to provide an index of reflection-impulsivity, or "the tendency to reflect on the validity of problem solving . . . when several possible alternatives are available and there is some uncertainty over which one is the most appropriate" (Messer, 1976, p. 1026). It contains a series of 12 match-to-target picture displays. During the MFFT, the child is asked to select the match to a target picture from among six highly likely alternatives. The outcome measures are mean latency to first selection of a match and total number of errors across all 12 items.

The traditional scoring method for the MFFT is a double median split procedure on scores for both outcome measures, resulting in the classification of subjects as reflective, impulsive, fast-accurate, or slow-inaccurate. This median split procedure has been criticized because of the loss of information and statistical power that results from dichotomizing the data and the limits on the generalizability of findings that result from sample-generated norms (Ault, Mitchell, & Hartmann, 1976; Salkind, 1978). These criticisms suggested that maintaining speed and accuracy as continuous variables was most appropriate.

The psychometric properties of the MFFT have received considerable attention in the developmental and educational research literature. Salkind (1977) developed a set of norms for the MFFT from research data in the published and unpublished literature. The resulting sample consisted of approximately 3000 middle class 5- to 12-year-old American children. Means and standard deviations for response latency and total errors by age and sex were calculated, as were mean correlations between latency and error data. Mean latencies for 5-and 6-year olds were 7.45 seconds (*s*=4.35) and 10.19 seconds (*s*=7.34) respectively. Mean total errors were 22.20 (*s*=7.06) and 17.96 (*s*=7.16) respectively. The mean correlation between latency and errors for 5- and 6-year olds was approximately -.43.

Ault et al. (1976) reviewed the psychometric properties of the MFFT latency and error measures. The 1-year test-retest reliability of the latency measure was .62 (Kagan, 1965). Test-retest reliabilities for the error scores have typically been lower, ranging from .23 (Messer, 1976) to .43 (Siegelman, 1969). Ault et al. (1976) also reported unpublished internal consistency reliability data. The reliability coefficients ranged from .32 to .60 for errors and were, once again, lower than those for latency.

The validity of the MFFT has also been investigated. Margolis, Leonard, Brannigan, and Heverly (1980) examined the relation between MFFT performance and performance on a number of standardized cognitive tasks among a sample of white, middle class kindergarten children. These tasks were rated on response uncertainty and included the Peabody Picture Vocabulary Test. They derived a composite Impulsivity score for the MFFT based on a procedure proposed by Salkind and Wright (1977). Margolis et al. observed that tasks identified as high in response uncertainty were the best predictors of composite Impulsivity scores and concluded that these results supported the construct validity of the MFFT among kindergarten children. Arizmendi, Paulsen, and Domino (1981) reviewed the validity data for the MFFT and concluded that existing data support the construct and predictive validity of the MFFT as a measure of reflection-impulsivity. Correlations between MFFT response latency and response latency on other match-to-target tests ranged from .33 to .52 (Kagan, 1965, 1966; Kagan et al., 1964). Messer (1976) concluded that the construct validity of the MFFT was supported by moderately robust stability over changes in the form of the MFFT and by relations between MFFT performance and performance on other measures with different task content.

The MFFT was administered according to standardized procedures. For each item, latency to first choice of a match and the number of incorrect choices were recorded. Eighty-four children completed the MFFT. Six children did not complete this measure, as three children did not participate in Visit 2, one child was extremely uncooperative throughout all testing, one child refused to participate in the MFFT, and time constraints prevented another child from completing this measure.

PPVT-R response latency. Response latency on the last six items (i.e. the ceiling items) on the PPVT-R was recorded. The mean response latency was used to provide an additional measure of impulsivity. This measure was obtained for 81 children. Three children did not participate in Visit 2. One child had recently been assessed with the PPVT-R, and therefore, did not complete this measure. Examiner error prevented the recording of response latency data for five children.

Behaviour ratings. The child's behaviour during administration of the McCarthy Scales and during the vigilance task was rated on a 1 (Not True or Never True) to 5 (Very True or Often True) scale on each of three aspects of attention -- inattention, impulsivity, and hyperactivity. Behavioural descriptions of each of these were derived primarily from the DSM III (1980):

> Inattention: The child fails to finish a task. The child often doesn't seem to listen and is easily distracted. The child has difficulty concentrating on tasks requiring sustained attention and has difficulty "sticking to" a task. The child may indulge in some avoidance behaviour.
>
> Impulsivity: The child appears to act before thinking, and has difficulty waiting for his/her turn. The child shifts excessively from one activity to

another and has difficulty organizing his/her work on a task. The child is unable to inhibit premature or repetitive responding on tasks or in situations that require focussed, reflective and organized effort.

Hyperactivity: The child has difficulty staying seated or sitting still and fidgets excessively. The child has difficulty keeping still or quiet when asked to do so.

A second rater observed 16% of the McCarthy Scale administrations and rated the child's behaviour on inattention, impulsivity, and hyperactivity. Inter-rater reliability was calculated by expressing the number of agreements as a percentage of the number of agreements plus the number of disagreements for each of the three aspects of attentional differences. The inter-rater reliabilities for inattention, impulsivity, and hyperactivity during the McCarthy testing session were .93, .71, and .86 respectively. All disagreements were within + or - one point on the rating scale. In order to obtain an estimate of inter-rater agreement beyond that expected by chance alone, Cohen's kappa coefficient (Cohen, 1960) was calculated for each aspect of attention. The kappa coefficients for inattention, impulsivity and hyperactivity during the McCarthy testing session were .88, .52 and .78 respectively, indicating a fair level of agreement for impulsivity ratings and an excellent level of agreement for inattention and hyperactivity ratings (Bakeman & Gottman, 1986).

The child's behaviour during the vigilance task games was also rated on inattention, impulsivity and hyperactivity. In order to obtain establish the stability of these aspects of child behaviour, a second rater conducted a brief interview following 23% of the vigilance task games and rated the child's behaviour during the interview. The stability of child behaviour across sessions was expressed by the Pearson correlations between ratings of inattention, impulsivity, and hyperactivity and the sum of these ratings obtained during the McCarthy and vigilance task sessions and those obtained during the interview session. The correlations between ratings of inattention, impulsivity, and hyperactivity were .42 ($p<.02$), .66 ($p<.001$), and .27 (NS) respectively for the McCarthy session and the interview session. There was a correlation of .64 ($p<.001$) between the sum of ratings of inattention, impulsivity, and hyperactivity for the McCarthy session and the sum of these ratings for the interview session. The correlations between ratings of inattention, impulsivity, and hyperactivity were .63, .82, and .69 ($p<.001$) respectively for the vigilance task session and the interview session. There was a correlation of .85 ($p<.001$) between the sum of the ratings for the vigilance session and the sum of these ratings for the interview session.

Parent report measures.

Three child behaviour questionnaires were completed by the mother. The Behavioral Style Questionnaire (McDevitt & Carey, 1978) and the Parenting Stress Index (Abidin, 1983) were administered to obtain information about child behaviour relevant to attentional differences among children. The Child Behavior Checklist (Achenbach & Edelbrock, 1983) provided information concerning child behaviour problems.

Behavioral Style Questionnaire. The Behavioral Style Questionnaire (McDevitt & Carey, 1978) is theoretically based in the concept of temperament introduced in the New York Longitudinal Study (Thomas & Chess, 1977) and was designed to measure "the behavioral style of the child in interaction with the environment" (McDevitt & Carey, 1978, p.245) in 3- to 7-year old children. The Behavioral Style Questionnaire (BSQ) consists of 100 items that describe child behaviour. Each item contains a description of child behaviour in a specific context. For example, "The child practices an activity until he/she masters it." represents the behavioural dimension of persistence. The parent rates each item, based on the child's recent behavior, on a six point rating scale from "almost never" to "almost always". The outcome measures include scores on the nine behavioural dimensions of activity, rhythmicity, approach/withdrawal, adaptability, intensity, mood, persistence, distractibility and sensory threshold. The behavioural dimensions relevant to the assessment of attentional differences were activity, persistence, distractibility, and sensory threshold.

The psychometric properties of the BSQ are satisfactory. It was standardized on 350 three- to seven-year old children in the test author's private pediatric practice. Means, standard deviations, and reliabilities for each of the nine behavioural dimensions were calculated. Test-retest reliability ranged from .67 to .94. Internal consistency reliabilty ranged from .47 to .80.

Carey, Fox, and McDevitt (1977) reported evidence for the validity of the BSQ. They found correlations between adaptability and persistence and success in the Matching Familiar Figures Test among a sample of 51 five- to seven-year old children. Significant stability in most dimensions have been reported as additional support for the validity of the BSQ (McDevitt, 1976).

The BSQ and the two other parent questionnaires were presented according to standardized instructions and with a letter of description. This letter is presented in Appendix A. The mothers of 77 children completed and returned the BSQ.

Parenting Stress Index. The Parenting Stress Index (Abidin, 1983) consists of 101 items that describe parental perceptions of child behaviour and the experience of parenting a specific child. For example, "Compared to most, my child has more difficulty concentrating and paying attention " represents the child domain subscale of distractibility/hyperactivity. The parent rates each item on a five point rating scale from "Strongly Agree" to "Strongly Disagree". The outcome measures are scores on the six child domain subscales of adaptability, acceptability, demandingness, mood, distractibility/hyperactivity, and reinforcement of parent; the seven parent domain subscales of depression, attachment, restriction of role, competence, isolation, relationship with spouse and health; as well as total scores for the child domain and parent domain scales. The subscale relevant to the assessment of attentional differences was distractibility/hyperactivity.

The psychometric properties of the Parenting Stress Index (PSI) are adequate. The test items were developed on the basis of a review of research on parent-child interactions, child psychopathology, and stress. The PSI was standardized on a predominantly white but demographically heterogeneous sample of approximately 500 normal and clinic-referred children seen in pediatric clinics in Virginia. Reliability and validity data are reviewed in the test manual. The PSI has satisfactory reliability. Internal consistency reliability coefficients range from .55 to .80 for the subscales and from .85 to .95 for the domain and total scale scores. Test-retest reliabilities reported in the literature and by the test author range from .55 to .81 for the child domain scores and from .70 to .91 for the parent domain scores (Abidin, 1983). The validity of the PSI is supported by the results of research on hyperactive children and family interactions. For example, Mash (1983, cited in Abidin, 1983) reported that the child domain score of the PSI effectively discriminated between hyperactive and normal children. The mothers of 80 children completed and returned the PSI.

The Child Behavior Checklist. The Child Behavior Checklist (Achenbach & Edelbrock, 1983) consists of 118 behaviour problem items and 20 social competence items. For example, "Can't concentrate, can't pay attention for long" represents a behaviour problem item. On the behaviour problem checklist, the parent rates the items as not true (0), somewhat or sometimes true (1), or very true or often true (2) of his/her child in the last 6 months. The Child Behaviour Checklist (CBCL) yields a profile of behaviour problems that has been standardized for sex and age. The behaviour problem outcome measures are raw and standard (T) scores on two broad band factors (internalizing and externalizing behaviour problems) and eight narrow band behaviour problem factors. The narrow band behaviour problem factors differ for 5-year-old girls and boys. The six narrow band factors of somatic complaints, depression, schizoid, withdrawal, aggression, and sex problems are common to all 5-year-old children. The factors of immaturity and delinquency are for 5-year-old boys; the factors of obesity and hyperactivity are for 5-year old girls. There are also three social competence factors.

The psychometric properties of the CBCL are quite satisfactory and it is considered to be one of the best of the parental report checklists available (Sattler, 1982). The behaviour problem factors were derived from an analysis of data obtained from a heterogeneous sample of 1300 clinic referred children. The CBCL was standardized on a heterogeneous sample of 1300 normal children. Reliability and validity data are reported in the test manual. The test-retest reliability coefficient is .84 for behaviour problems and .97 for social competence items. The construct validity of the CBCL has been supporteded by findings of the two broad band factors and several of the narrow band factors across many studies using different instruments (Achenbach & Edelbrock, 1983). The discriminant validity of the CBCL has been supported by the significantly higher behaviour problem scores and lower social competence scores of clinical samples (Achenbach & Edelbrock, 1983). The mothers of 79 children completed and returned the CBC.

Child demographic and environmental measures.

Parental interview. A structured parent interview was developed for the purposes of the current study. A copy of the parent interview is presented in Appendix II. The three main purposes of the interview were to update demographic information about the family; to obtain information about child health and medical history; and to obtain information necessary for completion of the HOME Inventory.

Demographic information. Maternal age and highest level of paternal and maternal education, in years, was recorded. The father's occupation was rated according to the Blishen scale, a measure of occupational status based on Canadian census data (Blishen & Roberts, 1976). In the case of single mothers, the mother's occupation was used. The parent was also asked to indicate an income category that corresponded to the total annual family income.

HOME Inventory. The preschool version of the HOME (Home Observation for the Measurement of the Environment) Inventory was used to obtain information about the quality of the child's physical and social environment for children between 3 and 6 years of age. A copy of the HOME Inventory is presented in Appendix II. The HOME (Caldwell & Bradley, 1984) is a checklist of items describing characteristics of the home environment that are associated with positive developmental outcomes. This checklist is completed by the examiner following a home visit. Items are scored as pass or fail on the basis of direct observation and/or questioning of the parent during the visit. The outcome measures are scores on the eight subscales of learning stimulation, language stimulation, physical environment, parental warmth, academic stimulation, modelling, variety of daily experience and physical punishment, as well as a total cumulative score.

The psychometric properties of the preschool version of the HOME are satisfactory. The HOME was standardized on a predominantly minority but demographically heterogeneous sample of 232 children and families in Little Rock, Arkansas. Reliability and validity data, obtained from a sample of 117 families in Syracuse, New York, are reported in the test manual. The reliability of the preschool HOME is acceptable. Internal consistency reliability estimates range from .53 to .83 for the subscales and is .93 for the total scale. Test-retest reliability data were derived from a small subsample. These subscale coefficients ranged from .05 to .70 and, due to the short length of several subscales and the 18 month interval between assessments, were considered to represent low estimates of reliability (Caldwell & Bradley, 1984).

The validity of the preschool HOME has been supported by significant correlations with measures of parental education and child cognitive development. Correlations with parental education ranged from .30 to .50 for the subscale scores and from .47 to .57 for the total score. Correlations with child IQ ranged from .36 to .50 for the subscale scores and from .58 for the total score.

In order to establish the reliability of potentially subjective items, nine of the observational items on the HOME Inventory were completed by a second rater during 18% of the second visits. These items, marked with asterisks in Appendix II, included all of the observational items on the Parental Warmth and the Physical Punishment subscales. Inter-rater reliability for each item was calculated by expressing the number of agreements on each item as a percentage of the number of agreements plus the number of disagreements for that item. The inter-rater reliabilities for the Parental Warmth items ranged from .81 to 1.00, and for the Physical Punishment items ranged from .88 to .94.

Maternal vocabulary. The PPVT-R (Dunn & Dunn, 1981) was administered to the mother to provide a measure of the quality of adult language in the child's home environment. The PPVT-R was administered according to instructions provided in the test manual. However, the standard administration procedure was modified in two ways in order to reduce the evaluative tone of the testing situation. First, testing began at the item that corresponds to the 14-year-old level and continued until the last test item had been completed. Second, rather than responding orally, the mothers recorded the number of the picture they had selected as correct for each item on an answer sheet.

The mothers of 58 children completed this measure. The mothers of 3 children refused to take the test; the mothers of . children became upset during the interview and testing was not considered appropriate. Time constraints prevented the mothers of 12 children from completing the test; examiner error prevented the mothers of 7 children from completing the test. One mother was not present during Visit 2; one mother had died prior to the current study; and three children did not participate in Visit 2.

# Results

*Overview*. The purpose of these analyses were to compare childhood outcomes to results reported in the literature. As much of this research has focused on differences between medical risk groups, two subgroups within the sample -- Small/Ill and Large/Well children -- were designated on the basis of immaturity and illness. These subgroups were compared on the childhood outcome measures. In addition, the mean scores of the Small/Ill subgroup were compared to the population means on the standardized cognitive and motor measures. Finally, data for the subgroups were combined and the results for the entire sample were summarized and reported.

*Designation of medical risk subgroups*.

Group differences on outcome measures -- between subgroups within a low birthweight sample, or between low birthweight children and a normal birthweight comparison group -- have been the focus of much of the research describing outcomes among low birthweight children. Due to the heterogeneity of the low birthweight population, there have been two possible approaches to describing differences between medical risk subgroups during childhood (Aylward et al., 1989; Salamy, Davis, Eldredge, Wakeley, & Tooley, 1988). One approach has been the comparison of subgroups designated on the basis of one variable -- either measures of neonatal immaturity or the presence or absence of a specific neonatal illness (Cohen, 1986; Hoy et al., 1988).

A second approach has been the comparison of subgroups designated on the basis of a summary of variables, that would represent the extent of medical involvement and deviation from the optimal course of events during the neonatal period (Aylward et al., 1989; Salamy et al., 1988).

Some recent reviews have included the suggestion that the first approach -- a designation of subgroups on the basis of individual variables -- may be one way to account for inconsistent findings in the literature and represents the best direction for future investigations (Cohen, 1986; Hoy et al., 1988). However, other reviewers have questioned this approach (Ornstein, Ohlsson, Edmonds, & Asztalos, 1990; Salamy et al., 1988; Scott, 1987). The first approach, a finer level of analysis of medical risk factors, has not necessarily resulted in consistent findings concerning the significance of a specific medical risk factor for childhood outcome (Ornstein et al., 1990). This has certainly been demonstrated by reports of comparisons of birthweight subgroups. Furthermore, this approach may divert the investigator's attention from a closer examination of other influences, such as environmental factors (Scott, 1987). In addition, neonatal medical risks are not mutually exclusive (Hunt et al., 1982). The identification of which, if any, medical risks are responsible for childhood outcome has been difficult, as low birthweight is accompanied by multiple risk factors that occur concurrently (Salamy et al., 1988). Therefore, the second approach, the designation of subgroups on the basis of a summary measure of medical risk variables, represented a useful alternative to the selection of one measure of medical risk as a basis for these comparisons.

Due to the heterogeneity of the current sample on measures of immaturity and illness, there were several possible subgroups that could be designated and compared on childhood outcome. These could include subgroups designated on the basis of immaturity (children with a birthweight ≤1500 g compared to children with a birthweight between 1501 and 2500 g), or on the basis of the presence of a specific neonatal illness (e.g. children who experienced respiratory distress syndrome compared to those who did not). Although either of these comparisons could be informative with respect to the impact of a specific medical risk factor, the purpose of the current study was to consider the broader question of the role of medical risk in subsequent development. Furthermore, subdividing the sample according to these specific medical risk factors might result in problems in making meaningful comparisons due to small numbers. Therefore, subgroups within the current sample were designated on the basis of both immaturity and illness, related factors that represent medical risks to the low birthweight infant, and compared on childhood cognitive, motor, attention, and behaviour measures.

With respect to immaturity, although a birthweight of less than 2500 g has been the criterion for low birthweight, it has been suggested that, within the low birthweight population, children with a birthweight between 2000 and 2500 g may be equivalent to the normal birthweight population with respect to morbidity and post-neonatal mortality (Caputo & Mandell, 1970, p. 364). It may also be quite likely that children born in 1990 at a birthweight of 2000 to 2500 g, without neonatal illness, would not be routinely admitted to neonatal intensive care as during 1982 to 1984, the birth years of children in the current study. With respect to illness, the morbidity scale used in the current study resulted in a summary measure of neonatal illness and also included a provision for designating the children as either Well or Ill.

Each child's morbidity score was used, according to criteria established during standardization of the scale (Minde et al., 1983), to classify the children as either Well or Ill. Children who had birthweights greater than or equal to 2000 g and were classified as Well were designated as Large/Well. These 27 children were conceptualized as a within-sample comparison group. Children who had birthweights less than 2000 g or were classified as Ill were designated as Small/Ill. The Small/Ill group, consisting of 63 children, therefore, included children who were small, ill or both, and was conceptualized as a within-sample high medical risk group. Within the Small/Ill subgroup, 32 children (51%) were less than 2000 g and Well; 7 (11%) were greater than 2000 g and Ill; the remaining 24 (38%) of the

Small/Ill subgroup were less than 2000 g and Ill. As both immaturity and illness were associated with longer hospitalization during the period following birth, and because the immaturity-by-illness categories resulted in unequal numbers of children in each cell, a factorial comparison was not considered conceptually or practically meaningful. Rather, the Large/Well and Small/Ill groups were compared.

These two subgroups were compared on measures of infant medical risk and environmental factors. These data are presented in Table 3. As expected from the manner in which the subgroups were designated, there were significant group differences on measures of birthweight, gestational age, morbidity, days in hospital and severity of RDS. There were no significant differences between the subgroups on most infant demographic and environment measures. Although mothers of Large/Well children had a higher educational level than mothers of Small/Ill children, there were no differences between the subgroups on HOME Inventory scores or maternal sensitivity ratings, measures of the quality of the infant environment. Therefore, the children who had been at lower medical risk, due to larger size and the absence of severe illness, could be conceptualized as a within-sample comparison group that was equivalent to the Small/Ill subgroup on most important environmental factors.

Table 3

Means and standard deviations of infant measures for medical risk subgroups

| | | Subgroup Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
|---|---|---|---|---|
| Medical risk | | | | |
| Birthweight | $M$ | 2268.3 | 1538.5 | 8.09** (88) |
| | $SD$ | 128.1 | 460.1 | |
| Gestational age | $M$ | 35.8 | 31.4 | 6.73** |
| | $SD$ | 2.6 | 3.0 | |
| Morbidity | $M$ | 44.6 | 72.6 | -3.38** |
| | $SD$ | 5.7 | 104.2 | |
| Days in hospital | $M$ | 11.8 | 49.1 | -6.56** |
| | $SD$ | 5.4 | 29.3 | |
| RDS severity | $M$ | 1.6 | 9.7 | -4.10** |
| | $SD$ | 2.8 | 9.4 | |

Table 3, cont'd.

Means and standard deviations of infant measures for medical risk subgroups

| | | Subgroup: Large/ Well ($n$=27) | Subgroup: Small/ Ill ($n$=63) | $t$ (df) |
|---|---|---|---|---|
| Demographic | | | | |
| Maternal age | $M$ | 26.3 | 25.8 | .49 |
| | $SD$ | 4.1 | 4.0 | |
| Maternal education | $M$ | 13.0 | 11.7 | 3.06* (88) |
| | $SD$ | 2.0 | 1.8 | |
| Paternal education | $M$ | 13.5 | 12.1 | 2.36 |
| | $SD$ | 2.6 | 2.6 | |
| Occupational status | $M$ | 39.3 | 36.3 | 1.05 |
| | $SD$ | 13.2 | 13.0 | |
| Environmental | | | | |
| 7 month HOME | $M$ | 5.3 | 5.5 | - .29 |
| | $SD$ | 2.1 | 1.9 | |

Table 3, cont'd.

Means and standard deviations of infant measures for medical risk subgroups

| | | Subgroup | | |
|---|---|---|---|---|
| | | Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
| Environmental | | | | |
| 12 month HOME | $M$ | 6.0 | 5.9 | .41 |
| | $SD$ | 1.7 | 2.0 | |
| 7 month | | | | |
| Sensitivity | $M$ | 5.9 | 5.8 | .54 |
| | $SD$ | 1.9 | 2.0 | |
| 12 month | | $n$=27 | $n$=61 | |
| Sensitivity | $M$ | 5.9 | 5.8 | .04 (86) |
| | $SD$ | 1.9 | 2.0 | |

$^{+}$ = $p$ <.05. $^{*}$ = $p$ <.01. $^{**}$ = $p$ <.001.

Description of cognitive and motor outcomes.

The Small/Ill subgroup was compared to both the Large/Well subgroup and the population means, obtained from the standardization samples, on the standardized global cognitive, language and motor outcome measures. As the general finding of the low birthweight research literature has been of normal global cognitive development, it was expected that mean scores on the global cognitive and language measures would be within the normal range for both medical risk subgroups. It was also expected that the mean score of the Small/Ill subgroup on the global cognitive measures would not be significantly lower than the mean scores of the Large/Well subgroup and the population mean. As there have also been reports of an increased risk for lower scores on measures of motor skills, it was expected that mean motor scores of the Small/Ill subgroup would be lower than both the mean scores of the Large/Well subgroup and the population means for the motor outcome measures.

T-tests were used to compare the 27 Large/Well children to the 63 Small/Ill children on outcomes that were the focus of the current study: mean scores for the McCarthy GCI, Verbal and Motor scales, the Developmental Test of Visual Motor Integration, and the Peabody Picture Vocabulary Test. Tests for a single large sample (McClave & Dietrich, 1988) were used to compare the mean scores of the Small/Ill subgroup to the population means on the global cognitive, language and motor measures. Due to the number of comparisons (10), the experimentwise error rate was set at .1, and the error rate per comparison was determined by dividing .1 by the number of comparisons and was thus set at .01 for each one-tailed comparison.

The McCarthy Scales of Children's Abilities. Each child's raw scores were transformed into standard scores on the General Cognitive Index (GCI) and on the five subscales according to standard procedures (McCarthy, 1972). The means and standard deviations for the GCI, Verbal, and Motor scores are presented in Table 4. (Mean scores for the Performance, Quantitative and Memory subscales are also reported.) For each of these measures, the mean scores for both subgroups were within the normal range. As expected, the mean McCarthy GCI and Verbal scores of the Small/Ill subgroup tended to be lower than those of the Large/Well subgroup, but these were not significant differences. The mean Motor subscale score of the Small/Ill subgroup was significantly lower than the means of the Large/Well subgroup and the population.

Developmental Test of Visual Motor Integration. Each child's raw score was transformed into an age equivalent score according to standard procedures (Beery & Buktenica, 1983). A score, the Visual Motor Index IQ (VMI IQ), was then derived from the ratio of the child's age equivalent score to the child's chronological age. This scoring method produced a score that was easier to interpret than the standard score (Siegel, 1983); a child whose performance was

Table 4

Means and standard deviations of standardized cognitive and motor measures for medical risk subgroups

| | | Subgroup | | | |
|---|---|---|---|---|---|
| | | Large/ Well | Small/ Ill | Subgroups[a] | Population[b] |
| | | (n=27) | (n=63) | t (df) | |
| McCarthy Scales | | n=26 | n=62 | | |
| GCI | M | 105.6 | 98.0 | 2.02 (86) | 1.03 (61) |
| | SD | 17.7 | 15.3 | | |
| Verbal | M | 55.5 | 50.2 | 1.94 | .14 |
| | SD | 12.2 | 11.3 | | |
| Perceptual-Performance | M | 51.2 | 48.3 | 1.25 | 1.39 |
| | SD | 10.6 | 9.6 | | |
| Quantitative | M | 50.6 | 47.5 | 1.58 | -2.25 |
| | SD | 7.8 | 8.7 | | |
| Memory | M | 52.6 | 45.7 | 2.74* | -3.03** |
| | SD | 9.7 | 11.2 | | |
| Motor | | n=26 | n=63 | | |
| | M | 46.4 | 42.3 | 1.52 (87) | -5.24** |
| | SD | 10.6 | 11.7 | | |

Table 4, cont'd.

Means and standard deviations of standardized cognitive and motor measures for medical risk subgroups

| | | Subgroup Large/ Well ($n$=27) | Subgroup Small/ Ill ($n$=63) | Subgroups $t$ (df) | Population $t$ (df) |
|---|---|---|---|---|---|
| VMI | | $n$=26 | $n$=59 | | |
| | $M$ | 90.8 | 89.6 | .46 (83) | -7.23** (58) |
| | $SD$ | 13.2 | 10.0 | | |
| PPVT-R | | $n$=27 | $n$=59 | | |
| | $M$ | 102.2 | 99.8 | .66 (84) | - .10 |
| | $SD$ | 17.2 | 15.3 | | |

[a] T-test for differences between the means of the two medical risk subgroups.

[b] T-test for differences between Small/Ill subgroup and the population means.

+ = $p$ <.05. * = $p$ <.01. ** = $p$ <.001.

at his/her age level would have a VMI IQ of 100. The means and the standard deviations for the VMI IQ are also presented in Table 4. The mean VMI of the subgroups were not significantly different. The mean of the Small/Ill subgroup was significantly lower than the population mean.

Peabody Picture Vocabulary Test-Revised. Each child's raw PPVT-R raw score was transformed into a standard score according to standard procedures (Dunn & Dunn, 1981). The means and standard deviations for the PPVT-R standard score are also presented in Table 4. As expected, the mean scores for both subgroups were within the normal range and were not significantly different. The mean score of the Small/Ill subgroup was not significantly different from the population mean.

Description of attention task and rating outcomes.

T-tests were used to compare the 27 Large/Well children to the 63 Small/Ill children on the means for the attention task measures and behaviour rating measures. These included two scores obtained from the vigilance task game; latency and error scores obtained from the Matching Familiar Figures Test; a latency score obtained from the Peabody Picture Vocabulary Test; and summary ratings of inattention, impulsivity and hyperactivity. Due to the number of comparisons (8), the experimentwise error rate was set at .1, and the error rate per comparison was determined by dividing .1 by the number of comparisons and was thus set at .01.

<u>Vigilance tasks</u>. Measures of sustained attention and impulsivity were derived from each vigilance task. For each child, the number of correct responses or hits (a bar press immediately following a presentation of the target letter X) and the number of incorrect responses or false alarms (a bar press immediately following a presentation of a non-target letter) were tabulated and converted to percentages. The hit rate was the number of correct responses expressed as a percentage of the total number of target letters presented. The false alarm rate was the number of incorrect responses expressed as a percentage of the total number of non-target letters presented.

A child's hit rate cannot be clearly interpreted without considering the child's false alarm rate (Swanson, 1983). For example, during the X Task, if Child A responded to all of the 30 target letter X's and none of the 120 non-target letters, Child A's hit rate was 100% (30/30) and the false alarm rate was 0% (0/120). If another child, Child B, responded to all 30 of the target letter X's, but also responded to 21 of the non-target letters, Child B's hit rate was also 100%, but the false alarm rate was 17.5% (21/120). Child A and Child B could not be meaningfully compared on the hit rate unless the false alarm rate were considered. Within the current sample, only two children had a hit rate of 100% and a false alarm rate of 0%.

Therefore, d', a measure of sustained attention that accounts for the false alarm rate was calculated according to procedures described in signal detection theory (Green & Swets, 1966). For each child, Z scores for the hit rate and for the false alarm rate were calculated. The measure of sustained attention, d', was the difference between the Z score for the hit rate and the Z score for the false alarm rate. In this example, Child A's d' score was 1.60 and Child B's d' score was .22.

A measure of impulsivity, i, was derived from the relative frequency of responses to non-target letters. This measure was the number of incorrect responses expressed as a percentage of the total number of responses (correct plus incorrect). Child A, who responded only to the target letter X, had an i score of 0% (0/(0 + 30)). Child B, who responded to all of the target letter X's (30), but also responded to 21 of the non-target letters, had an i score of 41.2% (21/(30 + 21)).

Eighty-three children completed the X Task, and there was consistency across the two vigilance tasks among the 59 children who completed both ($r$ =.78 for the d' scores; $r$ = .74 for the i scores). Therefore, only the measures from the X Task were used in subsequent analyses.

The means and standard deviations for d'(the measure of sustained attention), and i (the measure of impulsivity) for the X task are presented in Table 5. There was considerable variability on the d' and i scores. The d' scores ranged from -6.13 to 1.60 on the X task and the i scores ranged from 0% to 82% on the X Task. There were no significant

Table 5

Means and standard deviations of attention task and behaviour rating measures for medical risk subgroups

| | | Subgroup | | |
|---|---|---|---|---|
| | | Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
| Attention task | | | | |
| X Task | | $n$=24 | $n$=59 | |
| d' score | $M$ | .28 | - .11 | -1.03 (81) |
| | $SD$ | 1.15 | 1.70 | |
| i score (%) | $M$ | 15.42 | 21.98 | -1.39 (81) |
| | $SD$ | 13.97 | 21.34 | |
| MFFT | | $n$=25 | $n$=59 | |
| Latency | $M$ | 7.78 | 7.70 | .06 (82) |
| | $SD$ | 2.81 | 7.74 | |
| Errors | $M$ | 22.76 | 22.71 | .03 |
| | $SD$ | 6.86 | 7.52 | |
| PPVT-R | | $n$=23 | $n$=58 | |
| Latency | $M$ | 3.82 | 4.14 | - .56 (79) |
| | $SD$ | 2.39 | 2.26 | |

Table 5, cont'd.

Means and standard deviations of attention task and behaviour rating measures for medical risk subgroups

| | | Subgroup Large/ Well ($n$=27) | Subgroup Small/ Ill ($n$=63) | $t$ (df) |
|---|---|---|---|---|
| Behaviour measures | | | | |
| Ratings (%) | | $n$=27 | $n$=61 | |
| Inattention | $M$ | 50.74 | 54.10 | - .73 (86) |
| | $SD$ | 21.74 | 19.09 | |
| Impulsivity | $M$ | 44.81 | 44.92 | - .02 |
| | $SD$ | 22.93 | 19.97 | |
| Hyperactivity | $M$ | 42.96 | 46.40 | - .80 |
| | $SD$ | 18.77 | 18.44 | |

$^{+}$ = $p$ <.05. $^{*}$ = $p$ <.01. $^{**}$ = $p$ <.001.

differences between the medical risk subgroups on these measures.

Matching Familiar Figure Test. Two measures of impulsivity were derived from the MFFT. For each child, the mean latency to first selection of a match and the total number of errors were calculated. These measures were considered as describing continuous, rather than categorical, dimensions of the child's performance. The means and standard deviations for latency and total errors on the MFFT are also presented in Table 5. There was considerable variability on both measures. Mean response latencies ranged from 2.20 to 50.61 seconds. The total number of errors ranged from 4 to 40 (out of a possible total of 60 errors). There were no significant differences between the mean scores of the medical risk subgroups on these measures of impulsivity.

PPVT-R response latency. One measure of impulsivity was derived from the PPVT-R. For each child, the mean for latency to respond on the last six (ceiling) items on the PPVT-R was calculated. The means and standard deviations for this measure are also presented in Table 5. There was considerable variability on this measure. Mean response latencies ranged from 1.31 to 12.87 seconds. There was no significant difference between the mean scores of the medical risk subgroups.

Behaviour ratings. Each child's behaviour ratings on inattention, impulsivity, and hyperactivity were summed across the McCarthy and vigilance task sessions. These scores were then converted to percentages of the total possible score on each aspect. The mean percentage scores and standard deviations are also presented in Table 5. There were no significant differences between the medical risk subgroups on these behaviour rating measures.

Description of parent report measures.

The medical risk subgroups were compared on the behaviour measures obtained from the parent questionnaires. The primary purpose of the parent questionnaires --the Behavioral Style Questionnaire, the Parenting Stress Index, and the Child Behavior Checklist -- had been to obtain parent reports of child behaviour relevant to attentional differences. Scores on the parent domain subscales of the Parenting Stress Index described parent self-perceptions rather than perceptions of child behaviour. The primary focus of the Child Behavior Checklist was child behaviour problems. Furthermore, the narrow band behaviour problem factors were different for 5-year-old girls and boys, resulting in Hyperactivity scores for girls only. Therefore, PSI parent domain and CBC scores were not included in the medical risk subgroup comparisons and in subsequent analyses (although the mean scores will be reported).

T-tests were used to compare the Large/Well children to the Small/Ill children on the nine behavioural dimension scores of the BSQ and the six child domain subscales scores of the Parenting Stress Index. Due to the number of comparisons (15), it was necessary to control the Type 1 error rate. Therefore, the experimentwise error rate was set at .1, and the error rate per comparison was determined by dividing .1 by the number of comparisons and was thus set at .007 for each one-tailed comparison.

Behavioral Style Questionnaire. Each child's scores on the nine behavioural dimensions of the BSQ were calculated. The means and standard deviations for these scores are presented in Table 6. High scores indicated high activity level, arrhythmicity, withdrawal, low adaptability, intensity, negative mood, nonpersistence, distractibility and low sensory threshold. All of these scores were within the normal range.

The behavioural dimensions relevant to attentional differences were activity, persistence, distractibility and threshold. Although the Small/Ill subgroup tended to obtain higher scores on persistence and distractibility (indicating low persistence and greater distractibility, t-tests indicated that there were no significant differences between the medical risk subgroups on any of these measures.

Parenting Stress Index. Each child's raw scores on the subscales of the PSI were calculated according to standard procedures (Abidin, 1983). Mean raw scores were calculated for the six child domain subscales and the seven parent domain subscales; and for total child and parent domain scales. The means and standard deviations are also

Table 6

Means and standard deviations of parent report measures for medical risk subgroups

| | | Subgroup Large/ Well ($n$=27) | Subgroup Small/ Ill ($n$=63) | $t$ (df) |
|---|---|---|---|---|
| BSQ scores | | $n$=23 | $n$=54 | |
| Activity | $M$ | 3.38 | 3.47 | - .56 (75) |
| | $SD$ | .69 | .63 | |
| Rhythmicity | $M$ | 2.70 | 2.78 | - .55 |
| | $SD$ | .66 | .64 | |
| Approach | $M$ | 2.77 | 2.96 | -1.15 |
| | $SD$ | .76 | .62 | |
| Adaptability | $M$ | 2.40 | 2.70 | -1.86 |
| | $SD$ | .47 | .69 | |
| Intensity | $M$ | 4.07 | 4.37 | -1.79 |
| | $SD$ | .76 | .64 | |
| Mood | $M$ | 3.07 | 3.08 | - .02 |
| | $SD$ | .71 | .58 | |
| Persistence | $M$ | 2.74 | 3.04 | -1.62 |
| | $SD$ | .65 | .78 | |
| Distractibility | $M$ | 3.80 | 4.09 | -1.93 |
| | $SD$ | .60 | .59 | |

Table 6 cont'd.

Means and standard deviations of parent report measures for medical risk subgroups

| | | Subgroup | | |
|---|---|---|---|---|
| | | Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
| Threshold | $M$ | 3.82 | 3.89 | - .41 |
| | $SD$ | .67 | .62 | |
| PSI scores | | $n$=24 | $n$=56 | |
| Child domain | | | | |
| Adaptability | $M$ | 22.17 | 24.55 | $-2.05^{+}$ (78) |
| | $SD$ | 5.48 | 4.46 | |
| Acceptability | $M$ | 12.54 | 13.07 | - .60 |
| | $SD$ | 2.90 | 3.87 | |
| Demandingness | $M$ | 16.88 | 18.27 | -1.39 |
| | $SD$ | 4.07 | 4.10 | |
| Mood | $M$ | 9.33 | 10.29 | -1.48 |
| | $SD$ | 2.51 | 2.64 | |
| Distractibility/ Hyperactivity | $M$ | 20.83 | 21.32 | - .38 |
| | $SD$ | 5.71 | 5.07 | |
| Reinforcing | $M$ | 10.46 | 10.43 | .03 |
| | $SD$ | 4.83 | 2.74 | |

Table 6 cont'd.

Means and standard deviations of parent report measures for medical risk subgroups

| | | Subgroup | | |
|---|---|---|---|---|
| | | Large/ Well ($\underline{n}$=27) | Small/ Ill ($\underline{n}$=63) | $\underline{t}$ (df) |
| Parent domain | | | | |
| Depression | $\underline{M}$ | 17.92 | 19.32 | -1.09 (78) |
| | $\underline{SD}$ | 5.23 | 5.19 | |
| Attachment | $\underline{M}$ | 12.08 | 12.23 | - .18 |
| | $\underline{SD}$ | 4.09 | 3.00 | |
| Restriction | $\underline{M}$ | 16.33 | 16.93 | - .62 |
| | $\underline{SD}$ | 4.10 | 3.88 | |
| Competence | $\underline{M}$ | 29.75 | 29.23 | .33 |
| | $\underline{SD}$ | 6.07 | 6.69 | |
| Isolation | $\underline{M}$ | 11.67 | 13.07 | -1.62 |
| | $\underline{SD}$ | 3.88 | 3.40 | |
| Relationship with spouse | $\underline{M}$ | 17.13 | 16.09 | 1.05 |
| | $\underline{SD}$ | 4.08 | 3.99 | |
| Health | $\underline{M}$ | 11.17 | 11.88 | - .98 |
| | $\underline{SD}$ | 3.07 | 2.92 | |

Table 6 cont'd.

Means and standard deviations of parent report measures for medical risk subgroups

| | | Subgroup | | |
|---|---|---|---|---|
| | | Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
| CBCL | | ($n$=23) | ($n$=56) | |
| Somatic complaints | $M$ | 58.17 | 59.64 | - .94 (77) |
| | $SD$ | 5.40 | 6.60 | |
| Depression | $M$ | 56.39 | 58.14 | -1.57 |
| | $SD$ | 3.42 | 4.87 | |
| Schizoid | $M$ | 56.61 | 58.09 | -1.26 |
| | $SD$ | 4.56 | 4.84 | |
| Withdrawal | $M$ | 57.52 | 59.25 | -1.33 |
| | $SD$ | 4.47 | 5.54 | |
| Aggression | $M$ | 57.00 | 57.79 | - .58 |
| | $SD$ | 6.17 | 5.22 | |
| Sex problems | $M$ | 59.83 | 60.14 | - .24 |
| | $SD$ | 5.67 | 5.14 | |

Table 6 cont'd.

Means and standard deviations of parent report measures for medical risk subgroups

| | | Subgroup Large/ Well ($n$=27) | Small/ Ill ($n$=63) | $t$ (df) |
|---|---|---|---|---|
| CBCL | | | | |
| Girls (n=48) | | ($n$=15) | ($n$=33) | |
| Obesity | $M$ | 56.33 | 55.33 | 1.74 |
| | $SD$ | 3.16 | .74 | |
| Hyperactivity | $M$ | 56.07 | 57.76 | -1.12 |
| | $SD$ | 2.31 | 5.61 | |
| Boys (n=31) | | ($n$=8) | ($n$=23) | |
| Immaturity | $M$ | 58.75 | 61.52 | -1.07 (29) |
| | $SD$ | 7.50 | 5.85 | |
| Delinquency | $M$ | 59.00 | 59.22 | - .10 |
| | $SD$ | 7.27 | 4.74 | |

+ = $p$ <.05. * = $p$ <.01. ** = $p$ <.001.

presented in Table 6. High child domain scores indicated low adaptability, low acceptability to the parent, demandingness, negative mood, distractibility, and low reinforcement of the parent. All subscale scores were within the normal range. The subscale relevant to attentional differences was the distractibility/hyperactivty subscale. T-tests indicated that there were no significant subgroup differences, at the error rate set per comparison, on any of the child domain scores

Child Behavior Checklist. Each child's raw score on the narrow band behaviour problem factors were calculated. These raw scores were then transformed into T scores according to standard procedures (Achenbach & Edelbrock, 1982). The means and standard deviations for these scores are also presented in Table 6. All scores were within the normal range.

Description of outcomes for the entire sample.

There was no consistent pattern of reliable differences between the medical risk subgroups on the cognitive, motor, attention and behaviour outcome measures. The McCarthy Motor scale scores and the VMI score of the Small/Ill subgroup were significantly lower than the population means for these measures. There were no significant differences between the medical risk subgroups on the attention task measures, behaviour ratings, or behaviour measures obtained from parent-completed questionnaires. Therefore, because there was no consistent pattern of reliable differences between the two medical risk subgroups, the data for these two subgroups was combined for all subsequent analyses. The means and standard deviations of the entire sample for the cognitive and motor outcome measures, the attention task and behaviour rating measures, the BSQ behavioural dimensions, and the PSI child domain subscales are presented in Table 7. All scores on standardized measures were within the normal range. These data, as well as the results of the medical subgroup comparisons, indicate that the findings of the current study are generally consistent with previous descriptive research. The predictive value of medical risk, as well as environmental factors, in accounting for variability in outcome within the entire sample was considered in the next chapter of the thesis.

Table 7

Means and standard deviations of outcome measures for the entire sample (n=90)

| | M | SD |
|---|---|---|
| **Cognitive and motor measures** | | |
| McCarthy Scales (n=88) | | |
| GCI | 100.2 | 16.3 |
| Verbal | 51.8 | 11.7 |
| Perceptual-Performance | 49.1 | 9.9 |
| Quantitative | 48.4 | 8.5 |
| Memory | 47.7 | 11.2 |
| Motor[a] | 43.5 | 11.5 |
| Beery VMI IQ[b] | 89.9 | 11.0 |
| PPVT-R[c] | 100.5 | 15.8 |
| **Attention task and behaviour rating measures** | | |
| X Task (n=83) | | |
| d' score | .00 | 1.56 |
| i score (%) | 20.08 | 19.64 |
| MFFT (n=84) | | |
| Latency (seconds) | 7.72 | 6.23 |
| Total errors | 22.73 | 7.29 |
| PPVT-R (n=81) | | |
| Latency (seconds) | 4.05 | 2.29 |

Table 7, cont'd.

Means and standard deviations of outcome measures for the entire sample (n=90)

| | *M* | *SD* |
|---|---|---|
| **Behaviour ratings (%)** | | |
| Inattention | 53.0 | 20.0 |
| Impulsivity | 45.0 | 21.0 |
| Hyperactivity | 45.0 | 19.0 |
| **Parent report measures** | | |
| BSQ (*n*=77) | | |
| Activity | 3.44 | .64 |
| Rhythmicity | 2.76 | .64 |
| Approach/ Withdrawal | 2.90 | .67 |
| Adaptability | 2.64 | .64 |
| Intensity | 4.28 | .69 |
| Mood | 3.07 | .61 |
| Persistence | 2.95 | .75 |
| Distractibility | 4.00 | .60 |
| Threshold | 3.87 | .63 |

Table 7, cont'd.

Means and standard deviations of outcome measures for the entire sample (n=90)

| | M | SD |
| --- | --- | --- |
| PSI (n=80) | | |
| Adaptability | 23.84 | 4.88 |
| Acceptability | 12.91 | 3.59 |
| Demandingness | 17.85 | 4.13 |
| Mood | 10.00 | 2.65 |
| Distractibility/ Hyperactivity | 21.18 | 5.24 |
| Reinforcing | 10.44 | 3.46 |

[a] n = 89. [b] n = 85. [c] n = 86.

# Discussion

## Cognitive and motor outcomes

As expected, there are no significant differences between the medical risk subgroups on the McCarthy GCI, and no difference between the mean of the Small/Ill subgroup and the population mean. Reports of global cognitive outcome that have compared subgroups within a low birthweight sample have, in general, reported significantly lower mean scores only for extremely low birthweight (<1000 g) children within a low birthweight sample (Crisafi & Driscoll, 1989; Hunt et al., 1982; Mazer et al., 1988; Teberg et al., 1982). Studies that have included a normal birthweight comparison group have also included occasional reports of reliable differences between the mean scores of low birthweight and normal birthweight children (Field et al., 1983; Lloyd et al., 1988; Michelsson et al., 1984; Noble-Jamieson et al., 1982; Siegel, 1982), as well as reports of no differences between the scores of these two groups (Grigoroiu-Serbanescu, 1981; Holwerda-Kuipers, 1987; Jacob et al., 1984; Klein, 1988). Low birthweight may increase the risk for lower performance on global cognitive measures during early childhood. However, sample characteristics and the distribution of scores may influence the likelihood of reliable group differences on these measures. The results of the current study also support the notion that medical risk alone does not account for variability in global cognitive outcomes within a low birthweight sample.

The results of the current study are consistent with the results of several studies that have described language outcomes during early childhood (Astbury et al., 1987, 1990; Holmes et al., 1988; Jacob et al., 1984; Klein, 1988; Lloyd, 1984; Siegel, 1982, 1983; Nickel et al., 1982; Rose & Wallace, 1985a, 1985b; Wallace et al., 1982). Mean scores on the McCarthy Verbal scale and the Peabody Picture Vocabulary Test-Revised are within the normal range for both medical risk subgroups. As expected, there are no significant differences between the medical risk subgroups on the measures of language outcome, and no differences between the means of the Small/Ill subgroup and the population means.

The results of the current study are also consistent with the results of several studies that have described motor outcomes during early childhood. As expected from the results of these studies, the mean scores on the two motor measures are within the normal range and the mean scores of the Small/Ill subgroup on the motor outcome measures are lower than the population mean. These results are consistent with reports of low normal scores and high proportions of visual-motor problems among low birthweight and very low birthweight children (Ford et al., 1989; Forslund & Bjerre, 1989; Hirata et al., 1982; Hunt et al., 1982; Marlow et al., 1989; McDonald et al., 1989; Michelsson et al., 1984; Nickel et al., 1982; Siegel, 1982; Vohr & Garcia-Coll, 1985; Wallace et al., 1982; Whyte, 1981).

Unexpected findings. Contrary to the expectations derived from the research literature, there are no significant medical risk subgroup differences on the motor measures. There have been fairly consistent reports of differences in motor outcome between a low birthweight sample or subgroup and a comparison group in the literature. However, these studies focused on extremely low birthweight (<750 g) children (Crowe et al., 1986) and very low birthweight children who had experienced IVH, intraventricular hemorrhage (Williams et al., 1987). Extremely low birthweight children and children who experienced IVH represent very small proportions of the children in the current study. Studies that have included a normal birthweight comparison group have reported significantly lower mean scores on motor outcome measures among low birthweight children who experienced RDS (Field et al., 1983) and among very low birthweight children (Klein, 1988; Michelsson et al., 1984; Siegel, 1982). In contrast, the sample in the current study includes many children born at weights greater than 1500 g and who did not experience RDS during the neonatal period.

These results support the conclusions that the early childhood motor development of many low birthweight infants is normal, but that motor outcome scores may be lower relative to other aspects of functioning. The finding of no differences between medical risk subgroups on measures of motor outcome is not completely consistent with reports of the literature. However, these earlier reports have focused on children in some of the highest medical risk groups -- infants at extremely low birthweight, or infants with IVH and RDS. These results suggest, therefore, that although medical risk may contribute to lower scores on motor outcome within a low birthweight sample, the attribution of motor outcome to medical risk alone may not be supported.

The results of the current study support the conclusion that, for many low birthweight infants, global cognitive outcome during early childhood is normal and that an exclusive focus on global cognitive measures is of limited utility to our understanding of the consequences of low birthweight for subsequent development. These results also support the conclusion that the early childhood language and motor development of many low birthweight infants is normal. These results strongly suggest that, within a low birthweight sample, the attribution of differences in language and motor outcome to medical risk alone is unwarranted.

Attention outcome

Attention outcome has received relatively little systematic consideration in research on the consequences of low birthweight and a wide variety of measures have been used in the existing literature. There have been occasional reports of a high proportion of attention problems among very low birthweight samples. Most of the existing research includes a normal birthweight comparison group and there are inconsistent reports concerning differences between a low birthweight sample and a comparison group on measures of inattention, hyperactivity and impulsivity.

The results of the current study indicate a great deal of variability on measures of attention obtained from task measures, behaviour ratings and parent questionnaire scores. The comparison between medical risk subgroups within the current sample indicates that there are no sigificant differences on task, behaviour rating, or parent questionnaire measures of inattention, impulsivity, or hyperactivity.

The mean scores on the behavioural dimensions of the BSQ, the childhood temperament questionnaire, are within the normal range. There are no significant differences between the subgroups on the behavioural dimensions relevant to attention -- activity level, distractibility, persistence and sensory threshold. The mean scores on the PSI are within the normal range and there is no significant subgroup difference on the distractibility/hyperactivity subscale, although the Small/Ill group tended to have a higher score on the adaptability subscale.

The findings of normal or low scores on measures of distractibility and persistence and no medical risk subgroup differences on measures of inattention are not consistent with other reports of high scores relative to either a standardization sample or a normal birthweight comparison group. These reports include temperament measures (Field et al., 1983; Hertzig & Mittleman, 1984); behaviour ratings (Parkinson et al., 1986); and child behaviour questionnaires (Klein, 1988) in the assessment of inattention. Similarly, the finding of a normal score on a measure of sensory threshold and no difference between medical subgroups on task and rating measures of impulsivity is not consistent with studies that include temperament measures (Hertzig & Mittleman, 1984) and task measures (Siegel, 1983) in the assessment of impulsivity. However, the finding of a normal score on a measure of activity level, a low score on a questionnaire measure of distractibility/hyperactivity, and no subgroup difference on a rating of hyperactivity is consistent with other studies that use a temperament measure and reported activity level that was equivalent to (Hertzig & Mittleman, 1984) or less than (Parkinson et al., 1986) a normal birthweight comparison group.

Compared to other specific outcomes, such as motor skills, there is relatively little evidence concerning attention outcome among low birthweight children. For this reason, data concerning attention are essentially exploratory. The discrepancies between the pattern of findings in the current study and results reported in previous research may be attributable to a number of reasons. These reasons include the fact that a wide variety of measures have been used in existing research and the tendency to rely on individual, rather than multiple, measures of inattention, impulsivity, and hyperactivity.

## Chapter 2

### The prediction of childhood outcomes

Although retrospective research has indicated that many children with developmental and cognitive deficits have experienced some sort of early biological risk, prospective research has demonstrated that early risk does not clearly predict childhood outcome (Sameroff & Chandler, 1975). Predictive research on the consequences of low birthweight has been motivated and sustained by this "paradox" (Cohen, Sigman, Parmalee, & Beckwith, 1982), and by reports of optimal developmental outcome despite early medical risk.

A brief history of the literature will be presented. The review of literature that considers the prediction of outcomes among low birthweight children will focus on studies of children born since 1975 and assessed between 3 and 7 years of age. Reports of the prediction of global cognitive outcome will be summarized, and then reports of the prediction of language, motor, and attention outcomes among low birthweight children will be summarized. The implications of this research for the present study will then be presented.

History. Despite a focus on the description of outcomes and group differences, an interest in prediction has been evident throughout the history of low birthweight research. Despite secular changes, all eras of research have acknowledged the importance of both medical risk and environmental factors to the prediction of outcomes.

Benton (1940) reviewed research conducted during the first part of the 20th century and concluded that a lack of attention to important environmental factors (primarily socioeconomic status) might contribute to the discrepant findings and variability in outcomes described across studies. He critically reviewed the small number of studies that considered the predictive value of birthweight, concluding that birthweight alone was not a significant factor in the cognitive development of most low birthweight children and that more predictive research was needed (1940, p. 743).

In a review of the next era of research, Caputo and Mandell (1970) conceptualized environmental factors primarily as confounding variables, but presented conclusions that were similar to those presented in Benton's (1940) review. As in the case of the earlier research, although the smallest, most immature low birthweight subgroup were overrepresented among children with significant cognitive impairment, the relation between birthweight and cognitive outcome was not supported for most children (Caputo & Mandell, 1970). Furthermore, they concluded that environmental factors were important to childhood outcome, but their role as either correlates of medical risk or mediators of its impact was not clear. They also reviewed reports of language, motor and attention outcomes, as the research had begun to consider more than just global cognitive outcomes. Although these reports consisted mainly of retrospective research, Caputo and Mandell (1970) concluded that low birthweight appeared to be associated with an increased risk for language problems, impaired motor skills and hyperactivity.

In a review of research from the late 1960's onward, conducted during the period of the introduction of neonatal intensive care, Kopp (1983) presented several conclusions that were similar to those of both earlier reviews. Once again, there was considerable variability in childhood outcomes and the smallest, most immature subgroup appeared to be at the greatest risk for significant impairment, although outcome for many children was normal and medical risk was not necessarily associated with negative outcome. Kopp (1983) concluded, therefore, that although negative outcome may be associated with low birthweight, both have been related to poor environmental conditions, and optimal conditions may represent an important factor to childhood outcome.

Global cognitive outcome.

One approach to prediction has considered the predictive value of single measures of child characteristics or environmental factors. These potential predictors have included measures of medical risk, socioeconomic status, the quality of the infant environment, and infant developmental status. The general finding of this research has been that the predictive value of single measures is limited (Bee et al., 1982; Ross, Schechner, Frayer, & Auld, 1982), although this conclusion is not unanimous (Fagan & Singer, 1983). For both practical and theoretical reasons, then, the search for individual predictors of global cognitive outcome has continued in the low birthweight literature.

Medical risk. The research has generally reported modest or nonsignificant correlations between measures of neonatal medical risk and measures of global cognitive outcome during early childhood. There has, then, been a certain coherence between the results of this predictive research and the inconsistent pattern of findings in research describing medical risk group differences on childhood global cognitive measures.

Birthweight and gestational age, related measures of immaturity, have been the initial focus of attempts to identify a single predictor of childhood outcome. There have been several reports of nonsignificant correlations between either birthweight or gestational age and global cognitive outcome (Cohen & Parmalee, 1983; Hunt, 1981; Rose & Wallace, 1985b), and also reports of modest positive correlations between birthweight and childhood IQ scores (Largo, 1987; Largo, Pfister, Molinari, Kundu, Lipp, & Duc, 1989) and GCI scores (Williams et al., 1987), as well as modest negative correlations between gestational age and measures of global cognitive outcome (Largo, 1987; Siegel, 1982). The absolute value of these correlations has ranged from .24 to .40.

The predictive value of measures of neonatal illness, that is related to immaturity, has also been examined. Measures have included scores reflecting the presence and severity of specific illnesses such as RDS (respiratory distress syndrome), summary scores for medical complications, and total number of days in hospital. There have been several reports of no significant relations between such measures and early childhood IQ (Beckwith, 1984; Cohen & Parmalee, 1983; Hunt, 1981; Largo, Graf, Kundu, Hunziker, & Molinari, 1990; Rose & Wallace, 1985b; Williams et al., 1987), and also reports of modest negative correlations between neonatal illness and childhood IQ or GCI scores (Klein et al., 1985; Siegel, 1982; Skouteli, Dubowitz, Levene, & Miller, 1985). The absolute value of these correlations has ranged from .26 to .34.

_Environmental factors_. The general finding of research examining the relations between measures of infant environmental factors and global cognitive outcome during childhood has been that these relations are consistent and relatively greater than those reported for medical risk measures. Significant correlations between measures of demographic factors, obtained during infancy, and global cognitive outcome during childhood have been frequently reported across studies of low birthweight samples that have differed greatly with respect to medical risk. Existing evidence has also consistently demonstrated that the quality of the infant's physical and social environment is related to global cognitive outcome during childhood.

Measures of demographic factors have included the number of years of parental education, maternal age, and ratings of socioeconomic status based on parent education and occupation. Correlations between global cognitive outcome measures and parental education have ranged from .33 to .50 (Cohen & Parmalee, 1983; Hunt, 1981; Klein et al., 1985; Largo, 1987; O'Connor, Cohen, & Parmalee, 1984; Rose & Wallace, 1985b; Wallace et al., 1982); and those with socioeconomic status have ranged from .28 to .60 (Crisafi et al., 1989; Klein et al., 1985; Largo, 1987; Siegel, 1984; Wallace et al., 1982).

Measures of more qualitative aspects of the home environment have not received as much attention in the literature. The most commonly used standardized measure has been the HOME (Home Observation for Measurement of the Environment) Inventory (Bradley & Caldwell, 1974). Nonstandardized measures have been obtained from observations of caregiver/infant interactions. Although measures of the quality of the environment are in many cases correlated with demographic factors, they can also describe variability within socioeconomic groups and provide information about caregiver/infant interactions not available in demographic measures (McCall, 1976; Siegel, 1984). Siegel (1984) has reported a significant positive correlation between HOME Inventory scores obtained during infancy and the 5 year McCarthy GCI among a sample of very low birthweight children (*r*=.42). Similarly, Beckwith and Cohen (1984) have reported significant positive correlations between several measures of caregiver responsiveness during infancy and the Stanford-Binet IQ in sample of 5-year-old low birthweight children, even after the effect of socioeconomic status was partialled out (*r*'s from .24 to .50).

Relations between socioeconomic status and childhood outcome may be due, in part, to the relation between poor environmental conditions and an increased risk for low birthweight. Relations between measures of the quality of the environment and childhood outcomes may be due, in part, to the relations between these measures and measures of maternal education or maternal vocabulary, that may reflect the influence of genetic factors. As environmental factors include correlates of low birthweight (socioeconomic status) as well as possible mediators of the impact of medical risk (the quality of the caretaking environment), the predictive utility of both classes of environmental factors must be considered.

Infant status. The predictive validity of measures of infant development, such as the Bayley Mental Development Index (Bayley, 1969), for childhood development has been the subject of much interest and debate in longitudinal and risk research (Bornstein & Sigman, 1986; Fagan, 1984; Fagan & Singer, 1983; Ross et al., 1985; Siegel, 1979, 1983). Fagan and Singer (1983) reviewed the predictive validity of infant sensorimotor measures, and reported that, among high-risk samples, the median correlations between infant scores at 8-11 months and childhood IQ scores at 5-6 years were modest ($r$'s ranged from .23 to .29), but higher than those for normal samples. They also reported that the findings have been inconsistent among low birthweight samples, with some studies reporting good predictive validity (Drillien, 1961) and others reporting no relation between these infant measures and subsequent IQ scores (Caputo, Goldstein, & Taub, 1979).

More recent research has also demonstrated an inconsistent pattern of findings, but has confirmed the greater predictive value of these measures among low birthweight children. Several studies have reported significant correlations between sensorimotor measures obtained between 9 and 12 months and early childhood IQ and GCI scores in low birthweight samples (Astbury et al., 1990; Barrera & Kitching, 1990; Cohen & Parmalee, 1983; Hunt, 1981; McDonald et al., 1989; O'Connor et al., 1984; Ross et al., 1985; Siegel, 1979; Williams et al., 1987), although there have been exceptions (Rose & Wallace, 1985b). These correlations have ranged from .38 to .65.

Inconsistent findings may be attributable to several different factors. Among low birthweight infants, the range of scores is often wider than among normal birthweight infants (Ross, 1989), influencing the magnitude of the correlation between infant and childhood test scores. Between-study differences in sample characteristics and size may influence this range and, consequently, the magnitude of correlation coefficients, as well as the likelihood of a significant correlation and the generalizability of the finding (Ross, 1989). For example, Rose and Wallace's finding (1985b) of no significant correlation between Bayley scores and later IQ was obtained from a sample of less than 20 children. The age of testing during infancy may also influence the strength of relations with later measures. For example, test scores obtained at 12 months of age will be derived from a greater number of items than those obtained at 3 months. For 12-month old children, the Bayley includes items that assess the infants' manipulation of objects, imitation skills, eye-hand coordination, and vocalizations, as well as basic gross and fine motor skills. Therefore, 12-month scores might be more reliable, and also reflect a greater number of items that differentiate among children (Ross, 1989).

Conclusion. The research has suggested that, although a variety of individual variables have some predictive value for childhood outcome, a single variable that consistently predicts subsequent development has not been identified. Although medical risk has been related to global cognitive outcome, this relation has been modest and inconsistent, and relations with environmental factors have been more consistent. Although low birthweight may be related to an increased risk for negative childhood outcomes, the influence of environmental factors may be as important as the effects of medical risks (Aylward et al., 1989). Relations between measures of infant development and global cognitive outcome have also been reported, and inconsistent reports across studies have no doubt been influenced by methodological differences. However, these reports have provided substantial evidence for the relation of both medical and environmental factors, as well as infant status, to global cognitive outcome.

Multivariate approaches. A second approach to prediction has considered the multivariate relations between potential predictors and global cognitive outcome. This approach has included both multiple regression and categorical analytic methods. The general finding of this research has been that some combination of measures of medical risk, environmental factors, and infant status has provided the best prediction of global cognitive outcome. There is a certain coherence of these results with those of attempts to isolate individual predictors.

A limited number of studies have used a multiple regression approach and have focused on global cognitive outcomes (Crisafi et al., 1989; Crisafi, Driscoll, Rey, & Adler, 1987; Ross et al., 1985; Siegel, 1982a). Among studies that have considered infant factors, the results have been mixed with respect to medical risk, but have demonstrated the predictive utility of SES, that may reflect both biological and environmental factors. Siegel (1982a) reported that both medical risk and SES predicted global cognitive outcome in a sample of very low birthweight children. Stepwise multiple regression analyses indicated that SES, maternal education, the number of previous spontaneous abortions, birth order, and respiratory distress were significant predictors of ($R^2$=.26) the 5 year McCarthy GCI scores. However, Crisafi et al. (1987, 1989) reported that SES, rather than medical risk, predicted global cognitive outcome among very low birthweight children, a consistent finding when either Apgar scores, an index of medical risk (Crisafi et al., 1989), or aggregate measures of medical risk (Crisafi et al., 1987) were used in multiple regression analyses. The predictive power of measures of infant status has also been demonstrated. Crisafi et al. (1987) reported that, when 2 year Bayley MDI scores were entered into multiple regression anlayses, along with aggregate measures of medical risk and a measure of SES, SES was no longer a significant predictor of 6 year GCI. They concluded that the MDI score reflected the influence of infant medical risk and environmental factors on subsequent development. Ross et al. (1985) conducted a stepwise multiple regression analysis, indicating that 12-month Bayley MDI score and SES were significant predictors of 3-year Stanford-Binet IQ ($R^2$=.58).

The results of studies that have used categorical approaches to prediction have been consistent with the results of multiple regression analyses -- some combination of medical, environmental, and infant developmental measures provides the best prediction. One categorical approach has been to classify children on the basis of childhood test scores and compare groups on antecedent factors. For example, Cohen et al. (1982) reported both medical risk and infant status differentiated low IQ and normal IQ groups of low birthweight children. However, the low IQ group had significantly lower caregiving scores during the infancy period.

Another categorical approach has been to consider the stability of developmental status, and the results of these studies have been mixed. Hunt (1981) designated four developmental status categories during infancy and during childhood. Among children independently classified as a problem group, there was greater inconsistency in developmental status between infancy and childhood. Alternatively, Ross et al. (1985) designated three IQ categories during infancy and during early childhood and reported a significant correspondence between infant and childhood categories. However, when children were divided into low and high SES groups, the low SES group demonstrated a mean decline in scores between infancy and early childhood, whereas the high SES group demonstrated an increase.

A final categorical approach has been discriminant function analysis. Cohen and Parmalee (1983) used 9-month developmental test score, visual attention at 40 weeks gestational age, and object manipulation at 8 months in a discriminant function analysis and reported correct prediction rates of 67% and 74% for low IQ children and normal IQ children. Siegel (1982, 1983) classified children on the basis of a comparison between their predicted and actual McCarthy GCI scores. SES, maternal education and three medical risk measures yielded a correct prediction rate of 71%. When the 12 month Bayley MDI was added to the analysis, the correct prediction rate increased to 89%.

Despite the utility of categorical approaches for evaluating the accuracy of prediction, there are several disadvantages to these approaches relative to multiple regression. As they involve dichotomizing continuous data, categorical approaches inevitably result in a loss of information. The criteria for categorization have differed across studies, resulting in patterns of findings that are neither comparable nor consistent. Finally, categorization may also result in groups of disparate sizes and, therefore, difficulties in analysis and interpretation.

<u>The prediction of specific cognitive outcomes.</u>

Although reports of specific childhood outcomes have become a part of the descriptive research, there has been relatively less predictive research concerning these outcomes. Nonetheless, the findings of existing predictive research have indicated that the patterns of relations with predictor measures vary for different outcomes.

Language outcome. Measures of medical risk have not been consistently related to language outcome. A few studies have reported modest correlations between measures of immaturity and early childhood language outcome (Largo et al., 1986; Vohr & Garcia-Coll, 1985; Williams et al., 1987), whereas others have not (Rose & Wallace, 1985b). When the relation between environmental factors and language outcome have been reported, measures of demographic factors and the quality of the infant environment have been more consistently related to language outcomes than has medical risk (Largo, 1987; Largo et al., 1989; Rose & Wallace, 1985; Siegel, 1984; Vohr et al., 1989). There have also been reports of significant correlations between 12-month Bayley MDI and PDI scores and language outcome (McDonald et al., 1989; Ross et al., 1985; Siegel, 1982). Environmental factors and infant developmental status, then, have been more consistently related to language outcome than has medical risk, and may either reflect or mediate the impact of neonatal immaturity and illness.

Motor outcome. Measures of medical risk have been related to measures of visual motor integration and summary measures of motor outcome (Klein et al., 1985; Lindahl, 1987; Marlow et al., 1989; Williams et al., 1987). For example, Williams et al. (1987) reported a significant correlation between birthweight and the McCarthy Motor Scale score in a very low birthweight sample, and Klein et al. (1985) reported a significant negative correlation between measures of medical risk during infancy and childhood visual-motor skills. This finding has generally been reported across a variety of samples of low birthweight children, although there have been exceptions (Rose & Wallace, 1985b). There have been inconsistent reports of the predictive value of infant environmental factors for childhood motor outcome. For example, Siegel (1984) reported that infant socioeconomic status was not significantly related to the McCarthy Motor scale score in her very low birthweight sample. However, Klein et al. (1985) reported a significant correlation between parental education and motor outcome, suggesting that demographic measures may reflect both biological and environmental influences. Siegel (1984) has been among the limited number of investigators that have considered the relation between the quality of the environment and childhood motor outcome and has reported that there was no significant correlation between the infant HOME Inventory score and the McCarthy Motor scale score during early childhood. However, Bayley scores have been related to motor outcome. For example, Siegel (1983, 1984) reported significant correlations between the 12-month Bayley MDI and PDI scores and the McCarthy Motor Scale score.

In summary, medical risk has been related to early childhood motor deficits. However, child motor outcome has also been related to measures of socioeconomic status and infant developmental status, variables that may reflect both biological and environmental factors.

Attention outcome. In clinical and educational research, the study of predictors of early childhood attention problems has consisted mainly of retrospective research, and child characteristics have been investigated more thoroughly than environmental factors (Jacobvitz & Sroufe, 1987). This retrospective research has suggested that aspects of child behaviour, rather than medical risks such as low birthweight, may be one antecedent of early childhood attention problems (Campbell, 1985). There has been relatively little prospective research concerning the prediction of attention problems among low birthweight children.

In a review of clinical research on hyperactivity during early childhood, Campbell (1985) concluded that there was a need for prospective research investigating the contributions of both child characteristics and environmental factors. Recent formulations of attention problems have suggested that problems in the ability to regulate one's arousal level in response to environmental demands may be a child characteristic that contributes to attention problems (Douglas & Peters, 1979; Henker & Whalen, 1989). Evidence from existing prospective clinical research has suggested that environmental factors, such as the quality of parent/child interations, may interfere with the development of these self-regulatory processes and, therefore, be predictive of childhood attention problems. For example, as part of a prospective study of a disadvantaged, low SES sample, Jacobvitz and Sroufe (1987) reported that maternal intrusiveness during infancy and overstimulation during early childhood were related to distractibility and hyperactivity at 6 years of age. However, neonatal status and infant temperament were not predictive of either of these aspects of attention.

In the prospective low birthweight literature, reports of correlations between either medical risk or environmental factors and childhood attention outcomes have been rare. However, infant developmental status and behaviour have been related to early childhood attention problems (Astbury et al., 1987; Largo et al., 1990; Siegel, 1983). For example, Siegel (1983) reported significant correlations between Bayley scores and a task measure of impulsivity during childhood, and Astbury et al. (1987) reported a significant relation between 2-year Bayley scores and a rating measure of childhood attention problems. However, Ross et al. (1985) reported no correlation between Bayley scores and ratings of hyperactivity during early childhood. There have also been reports of significant correlations between ratings of infant behaviour and measures of childhood attention problems (Ruff, Lawson, Parrinello, & Weissberg, 1990; Sigman et al., 1987). For example, Ruff et al. (1990) derived both aggregate quantitative measures of inattention and impulsivity and qualitative rating measures of behaviour during developmental testing at 12 months. Among preterm infants in their sample, these measures were modestly related to similar measures obtained during early childhood assessments and to maternal reports of inattention, impulsivity and hyperactivity.

Conclusion. Positive correlations between child language outcome and both environmental factors and infant developmental status have been fairly consistently reported. Medical risk has been related to motor outcome during early childhood, as have measures of socioeconomic status and infant developmental status. Finally, existing evidence has suggested that measures of environmental factors and infant status may be correlated with early childhood attention outcome.

Multivariate approaches. The multivariate prediction of language, motor and attention outcomes has been investigated in a very limited number of studies. Siegel (1982, 1983) determined the predictive value of individual measures of medical risk, socioeconomic status, and parent education for McCarthy Verbal and Motor scale scores; measures of vocabulary and visual-motor integration; and a task measure of impulsivity. Linear stepwise multiple regression analyses indicated that medical risk measures were more likely to be significant predictors of motor and attention outcomes, whereas environmental measures were more likely to be significant predictors of verbal outcome. When 12-month Bayley scores were entered into the analyses, they significantly increased the multiple R for verbal outcome only. Crisafi et al. (1987) submitted a measure of SES and scores based on two aggregate medical risk factors to a series of multiple regression analyses, and reported that neither medical risk factor was a significant predictor of McCarthy Verbal or Motor scale scores.

Implications for the current study.

Several general trends have been discerned in the predictive research literature. The predictive value of single measures is limited, and most multivariate studies have focused on global cognitive outcomes. The results of a limited number of studies that have used a multivariate approach have suggested that the predictive value of immaturity and illness, socioeconomic status, the quality of the infant environment and infant status may differ for different domains of development, a conclusion that is consistent with that of a recent meta-analysis of the follow-up literature (Aylward et al., 1989).

The results of this predictive research have several implications for the current study. The predictive value of measures of medical risk, infant environmental factors, infant developmental status, and early childhood environmental factors was considered in a multivariate approach to prediction. When possible, aggregate predictor and outcome measures were developed in order to utilize multiple sources of information about the constructs of interest, and to enhance the representativeness and reliability of these measures. Measures of both immaturity and illness were considered in the aggregate measure of medical risk, and measures of both socioeconomic status and the quality of the environment were considered. The multiple assessments of language, motor and attention outcomes were incorporated into aggregate measures of these childhood outcomes. Finally, parallel predictive analyses were conducted for both global and specific outcomes.

## Hypotheses

On the basis of previous research, it was expected that infant developmental status and the quality of the environment would predict global cognitive and language outcome; and that neonatal immaturity and illness and infant developmental status would be significant predictors of child motor outcome. Prediction analyses concerning attention outcome would be essentially exploratory. On the basis of existing prospective research on attention problems, it was expected that both infant developmental status and the quality of the environment would predict attention outcome.

## Method

*Overview*. The purposes of the next set of analyses, conducted on the data obtained from children participating in the current study, were to develop aggregate outcome and predictor measures and to develop the best prediction equation for each of the childhood outcomes. Missing data analyses were conducted prior to the development of aggregate measures. As a result of these analyses, presented in Appendix III, aggregate measures were developed from existing measures available for each subject.

Aggregate measures were developed on the basis of both conceptual and statistical relations among individual measures of the construct of interest. Aggregate measures of immaturity/illness, infant socioeconomic status, the quality of the infant environment, and childhood socioeconomic status were developed. These aggregates, along with measures of infant developmental status and the quality of the child environment, were considered as potential predictors of childhood outcomes. Aggregate language, motor, and attention outcome measures were developed. These aggregates, along with global cognitive outcome, were the criterion measures in a series of multiple regression analyses. These multiple regression analyses were conducted in three phases to consider the predictive utility of a) infant factors (immaturity/illness, socioeconomic status, and the quality of the environment), b) infant developmental status, and c) concurrent child environmental factors (socioeconomic status and the quality of the environment).

Aggregation of measures.

The rationale for aggregation. Aggregation is the measurement of a construct using the sum or mean of more than one assessment of that construct (Paunonen & Gardner, 1989). The rationale for aggregation is that the resulting aggregate measure will have conceptual and statistical advantages over a single measure of the construct. An aggregate enables the researcher to focus on a construct of interest and reduce the number of measures while retaining as much information as possible. Furthermore, an aggregate measure will be more stable and free of error and will account for a larger proportion of the true variance in criterion measures than one single measure (Paunonen & Gardner, 1989; Rushton, Brainerd, & Pressley, 1983).

Aggregation was particularly relevant to the current study. For example, potential predictors of childhood outcome were available in a cluster of related measures of medical risk -- birthweight, gestational age, morbidity, the number of days in hospital, and the severity of RDS. (In this example, the absolute values of the intercorrelations ranged from .40 to .84.) The use of only one of these measures would have resulted in a loss of information and presented difficulties in the interpretation of results. For example, suppose birthweight were chosen as a potential predictor of childhood outcome. As correlations are influenced by error and sample characteristics, the choice of birthweight over other measures of medical risk would be, in some sense, arbitrary.

The use of all five measures of medical risk as predictors would have been statistically problematic and also presented difficulties in the interpretation of results. The intercorrelations among these measures indicate a high degree of redundant information, or multicollinearity. Within a study, this may result in the inaccurate estimation of regression statistics, thereby influencing the nature of the best prediction equation and inferences about the predictive utility of the construct of interest (Pedhazur, 1982). For example, the regression coefficient obtained for birthweight alone would be divided among the five correlated predictors (Pedhazur, 1982), possibly leadin, to omission of any measures of medical risk from the prediction equation. Across studies, differences in the intercorrelations among predictors might result in large differences in regression coefficients and, consequently, inconsistencies in the results of different studies of the same phenomenon (Pedhazur, 1982). For these reasons, aggregation represented a meaningful alternative to either the choice of one measure of each of the constructs of interest or the use of several individual intercorrelated measures.

<u>The approach to aggregation</u>. The approach to aggregation was to focus on the internal consistency of

components of the aggregate, considering both conceptual and statistical criteria. Following the selection of measures, principal components analyses were conducted, but a Z-score approach to aggregation was chosen, as it incorporated both conceptual and statistical criteria and generated a score for each child despite missing values. For each construct of interest, the measures obtained for a particular child were transformed into Z-scores and averaged to yield an aggregate.

Aggregation of language and motor outcome measures.

Correlational analyses of child cognitive and motor outcome measures were conducted and aggregate measures of language and motor outcomes were developed. The standardized scale score was used as a measure of global cognitive outcome.

There were statistical relations among conceptually related scores. These data are presented in Table 8. There were significant intercorrelations among the McCarthy GCI and the five scale scores. These correlations are due, in part, to the content overlap among the five scale scores and to the fact that the GCI is itself an aggregate of the Verbal, Perceptual-Performance, and Quantitative scales scores. As performance, quantitative and memory outcomes were not the focus of the current study, the McCarthy subscale scores on these specific aspects of functioning were not included in subsequent analyses.

Table 8

Intercorrelations among child cognitive and motor outcome measures (n=88)

| Measure | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 1. GCI[1] | .87 | .72 | .78 | .83 | .52 | .49 [a] | .74[b] |
| 2. Verbal | | .38 | .60 | .79 | .25 | .35[a] | .69[b] |
| 3. Performance | | | .42 | .38 | .72 | .58[a] | .37[b] |
| 4. Quantitative | | | | .80 | .37 | .28[a] | .59[b] |
| 5. Memory | | | | | .35 | .28[a] | .59[b] |
| 6. Motor | | | | | | .63[b] | .19[c] |
| 7. VMI | | | | | | | .36[c] |
| 8. PPVT-R | | | | | | | |

[1] The GCI is the sum of measures 2, 3, and 4. Measures 2, 4, and 5 contain all of the verbal items of the McCarthy Scales.

[a] $\underline{n}$ = 83. [b] $\underline{n}$ = 84. [c] $\underline{n}$ = 85.

For $\underline{n}$ = 83, correlation coefficients ($\underline{r}$) with an absolute value of .28 or greater are significantly different from 0 at $\underline{p}$ <.005.

The correlations between the McCarthy scale scores and the PPVT-R and the Beery VMI IQ demonstrated the consistency of different measures of the same aspect of functioning. The PPVT-R was strongly related to the McCarthy Verbal scale ($r$ = .69); the VMI IQ was strongly related to the McCarthy Motor scale ($r$ = .63). There were, then, conceptually and statistically meaningful relations among language measures and among motor measures.

The McCarthy Verbal scale score is a measure of expressive language and verbal memory, and the PPVT-R standard score is a measure of receptive language. Therefore, these two scores were aggregated to provide a measure of language outcome. The child's scores on these measures were transformed into Z scores and the two Z scores were averaged to yield an aggregate measure of language outcome. The McCarthy Motor scale includes fine-motor and gross-motor items, and the Beery VMI IQ provides an additional measure of fine-motor skills. Therefore, these two measures were aggregated to provide a measure of motor development. The child's scores on each measures were transformed into Z scores and the two Z scores were averaged to yield an aggregate motor outcome measure. The McCarthy GCI was retained as a global outcome measure.

Aggregation of attention outcome measures.

Overview. The expected pattern of statistical relations among measures of inattention, impulsivity, and hyperactivity was considered prior to aggregation. Task measures of inattention and impulsivity were then developed. Next, relations among task measures, examiner ratings of inattention, impulsivity and hyperactivity, and parent reports of child behaviour were compared to the expected pattern. Parent report measures were then selected for aggregation with task and rating measures. A principal components analysis was conducted on task, rating and parent report measures. Method variance appeared to influence the outcome of this analysis, as items obtained from the same type of measure (task measures, rating measures, and parent report measures) clustered together. Furthermore, factor scores required full data on each subject. Therefore, Z-score approach to aggregation was chosen, yielding aggregate measures of three aspects of attention outcome -- inattention, impulsivity, and hyperactivity.

Expected pattern of relations among measures. The expected pattern of relations among the multiple measures of attention are presented in Table 9. It was expected that inattention would be comprised of: a low score on the task measure of sustained attention (d' score); high ratings on inattention; and parent reports of nonpersistence and distractibility. It was expected that impulsivity would be comprised of high scores on the vigilance task measure of impulsivity (i score), a high error score on the MFFT, and low latency scores on the MFFT and the PPVT-R; high ratings on impulsivity; and parent reports of nonpersistence, high sensory threshold and distractibility. (A high sensory

Table 9

Expected pattern of relations among measures of inattention, impulsivity, and hyperactivity

| Measure | Inattention | Impulsivity | Hyperactivity |
|---|---|---|---|
| Task | | | |
| X Task | Low d' score | High i score | |
| MFFT | | High errors<br>Low latency | |
| PPVT-R | | Low latency | |
| Rating | Inattention | Impulsivity | Hyperactivity |
| Parent report | | | |
| BSQ | Non-persistence<br>Distractibility | Non-persistence<br>High threshold | High activity |
| PSI | Distract-ibility[1] | Distract-ibility | Distract-ibility |

[1] PSI Distractibility/Hyperactivity score.

threshold would indicate a child who was less likely to detect changes in visual stimuli and, therefore, was expected to have a low response latency and a high number of incorrect and impulsive responses on the vigilance task and the MFFT.) It was expected that hyperactivity would be comprised of high ratings on hyperactivity; and parent reports of high activity level and distractibility.

Attention task measures. A correlational analysis of the attention task measures was conducted. These data are presented in Table 10. As expected, there were significant statistical relations among the multiple measures of impulsivity. The impulsivity (i) score on the vigilance task was positively related to MFFT total errors. Mean MFFT response latency and total errors on the MFFT were negatively correlated. The MFFT and PPVT-R response latency measures were significantly correlated.

A task measure of inattention and an aggregate task measure of impulsivity were developed for each child. The task measure of inattention was the d' score, negatively weighted in order to represent inattention (rather than sustained attention). Task measures of impulsivity were transformed into Z-scores and averaged to yield an aggregate task measure of impulsivity.

Correlations between attention task and behaviour ratings measures. A correlational analysis of attention task measures and the behaviour rating measures was conducted. These data are presented in Table 11. The task

Table 10

Intercorrelations among attention task measures

| Measure | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Inattention | | | | |
| 1. d' score | -.83[a] | .21[b] | -.32[b] | -.04[c] |
| Impulsivity | | | | |
| 2. i score | | -.17[b] | .32[b] | .10[c] |
| 3. MFFT latency | | | -.47[d] | .38[e] |
| 4. MFFT errors | | | | -.14[e] |
| 5. PPVT-R latency | | | | |

[a] $n$ = 83. [b] $n$ = 82. [c] $n$ = 79. [d] $n$ = 84. [e] $n$ = 80.

For $n$ = 80, correlation coefficients ($r$) with an absolute value of .28 or greater are significantly different from 0 at $p<.005$.

Table 11

Correlations between attention task and behaviour rating measures (n=83)

| | Task Measure | |
|---|---|---|
| Rating | Inattention | Impulsivity |
| Inattention | .58 | .51[a] |
| Impulsivity | .47 | .53[a] |
| Hyperactivity | .25 | .31[a] |

[a] $n$ = 85.

For $n$ = 83, correlation coefficients ($r$) with an absolute value of .28 or greater are significantly different from 0 at $p$<.005.

measures were the inattention measure derived from the negatively weighted d' score and the aggregate task measure of impulsivity.

As expected, there was a positive correlation between the task measure of inattention and the behaviour rating measure of inattention. Similarly, the aggregate task measure of impulsivity was positively correlated with the behaviour rating of impulsivity.

Correlations between parent reports and attention task and behaviour rating measures. A correlational analysis of parent report measures and attention task and behaviour rating measures was conducted. The parent report measures were scores on the nine behavioural dimensions of the Behavioral Style Questionnaire (BSQ) and scores on the six child domain subscales of the Parenting Stress Index PSI).

These data are presented in Table 12. High scores on the BSQ measures indicate high activity level, arrhythmicity, withdrawal, slow adaptability, intensity, negative mood, nonpersistence, distractibility and a low sensory threshold. High scores on the PSI measures indicate low adaptability, low acceptability to the parent, demandingness, negative mood, distractibility/hyperactivity, and low reinforcement of the parent.

As expected, there were significant correlations between task and behaviour rating measures, and parent reports of child behaviour relevant to the construct of attention. In addition, these data also indicated that task

Table 12

Correlations between task, behaviour rating and parent report measures of inattention, impulsivity and hyperactivity

| | Task and Behaviour Rating Measures | | | | |
|---|---|---|---|---|---|
| | Inattention | | Impulsivity | | Hyperactivity |
| Parent report | Task | Rating | Task | Rating | Rating |
| BSQ | | | | | |
| Activity | .16[a] | .16 | .25[b] | .31 | .29* |
| Rhythmicity | .01 | .16 | -.03 | -.19 | .22 |
| Approach/ Withdrawal | -.01 | -.08 | -.02 | -.19 | -.24 |
| Adaptability | .29* | .37* | .40* | .27 | .39* |
| Intensity | .08 | .02 | .14 | .17 | .14 |
| Mood | .14 | .14 | .28 | .12 | .13 |
| Persistence | .36* | .31* | .53* | .18 | .28 |
| Distractibility | .03 | .09 | .01 | .08 | .14 |
| Threshold | -.25 | -.13 | -.29* | .03 | -.07 |
| PSI | | | | | |
| Adaptability | .16[b] | .08 | .14[c] | .10 | .18 |
| Acceptability | .32* | .28 | .25 | .25 | .32* |
| Demandingness | .35* | .31* | .38* | .29* | .33* |
| Mood | .05 | .18 | .05 | .18 | .30* |
| Distractibility | .30* | .41* | .39* | .47* | .60* |
| Reinforcing | .05 | .22 | -.12 | .17 | .32* |

[a] $n = 75$. [b] $n = 77$. [c] $n = 79$. * = For $n = 75$, correlation coefficients with an absolute value of .29 or greater are significantly different from 0 at $p<.005$.

and behaviour rating measures of inattention, impulsivity and hyperactivity were related to parent reports of other aspects of child behaviour.

Both the task and behaviour rating measures of inattention was related to nonpersistence (BSQ) and distractibility/hyperactivity (PSI). However, the task measure of inattention was also related to low adaptability (BSQ), low acceptability, and demandingness (PSI); the rating of inattention was related to low adaptability (BSQ) and demandingness (PSI).

The aggregate task measure of impulsivity was positively related to nonpersistence, negatively related to low sensory threshold (BSQ), and positively related to distractibility/hyperactivity (PSI). The rating of impulsivity was correlated with high activity level (BSQ) and distractibility/hyperactivity (PSI). However, the task measure of impulsivity was also related to low adaptability (BSQ) and demandingness (PSI). The rating of impulsivity was related to demandingness (PSI).

The rating of hyperactivity was correlated with high activity level (BSQ) and distractibility/hyperactivity (PSI). Furthermore, the rating of hyperactivity was also positively correlated with a number of parent report measures of difficult and stressful child behaviour -- low adaptability (BSQ), low acceptability, demandingness, negative mood, and low reinforcement of the parent (PSI).

There were, then, consistent statistical relations between measures of attention obtained from task performance and examiner ratings of child behaviour, and parent reports of child behaviour relevant to the construct of attention. In addition, task and rating measures of inattention, impulsivity, and, in particular, hyperactivity, were positively correlated with parent report measures of difficult and stressful child behaviour.

Observed pattern of relations among measures of inattention, impulsivity and hyperactivity. The observed pattern of relations among the multiple measures of attention are presented and compared to the expected pattern of relations in Table 13. This comparison indicated a close correspondence between expected and observed patterns of relations.

As expected, inattention was comprised of inattention on the vigilance task; inattentive behaviour during two testing sessions; and parent reports of nonpersistence and distractibility/hyperactivity. Impulsivity was comprised of premature and inaccurate responses across three tasks; impulsive behaviour during two testing sessions; and parent reports of nonpersistence, a high sensory threshold, and distractibility/hyperactivity. Finally, hyperactivity was comprised of hyperactive behaviour during two testing sessions and parent reports of high activity level and distractibility/hyperactivity.

Table 13

Observed pattern of relations among attention measures

| Measure | Inattention | Impulsivity | Hyperactivity |
|---|---|---|---|
| Task | | | |
| X Task | Low d' score[E] | High i score[E] | |
| MFFT | | High errors[E] | |
| | | Low latency[E] | |
| PPVT-R | | Low latency[E] | |
| Rating | Inattention[E] | Impulsivity[E] | Hyperactivity[E] |
| Parent report | | | |
| BSQ | | High activity | High activity[E] |
| | Non-persistence[E] | Non-persistence[E] | |
| | | High threshold[E] | |
| | Slow adaptability | Slow adaptability | Slow adaptability |
| PSI | Distractibility[E] | Distractibility[E] | Distractibility[E] |
| | Low acceptability | | Low acceptability |
| | Demandingness | Demandingness | Demandingness |
| | | | Negative mood |
| | | | Low reinforcement |

---

E = Part of expected pattern of relations among measures of inattention, impulsivity, and hyperactivity.

The observed pattern of relations differed from the expected pattern in three respects. First, the BSQ measure of distractibility was not related to task and behaviour measures of inattention. Second, the BSQ measure of activity level was related to the rating measure of impulsivity. Finally, the pattern of observed relations included significant correlations between task and rating measures of inattention, impulsivity and hyperactivity and parent reports of difficult and stressful child behaviour.

The purpose of the questionnaires had been to obtain parent report measures that could be combined with task and rating measures in order to provide more representative and reliable measures of childhood attention outcome. The expected pattern had not included child behaviours that might be important correlates or associated features of inattention, impulsivity, and hyperactivity -- low adaptability, low acceptability to the parent, demandingness, negative mood, and low reinforcement of the parent. The findings of these relations is, however, quite consistent with clinical research on attention deficits and hyperactivity. High scores on these subscales are one aspect of the profile of the hyperactive child reported by the author of the PSI (Abidin, 1983). Clinical research has demonstrated that early childhood attention deficits are characterised by the principal features of inattention, impulsivity and hyperactivity, as well as by associated features such as behaviour problems and noncompliance

(Campbell, 1985). Factor analytic studies have also demonstrated content overlap between questionnaire subscales assessing attention problems and behaviour problems (Cohen, 1986). Finally, clinical research on child hyperactivity and family interactions has demonstrated that measures of parenting stress related to child behaviour, such as the Child Domain of the PSI, are among the most efficient discriminators of hyperactive and normal children (Mash & Johnston, 1983).

The selection of parent report measures on the basis of expected relations alone may not have resulted in the most meaningful aggregate. As attention problems often co-exist with difficult and stressful child behaviours (Douglas & Peters, 1979; Krupski, 1986), the observed statistical relations between parent report measures and task and rating measures of attention were suggestive of a meaningful conceptual relation. Therefore, the inclusion of parent reports of difficult and stressful child behaviour in aggregate measures of inattention, impulsivity and hyperactivity was consistent with the findings of clincial research and seemed "more reflective of psychological reality" (Rushton et al., 1983, p.21).

Aggregation of attention measures. Expected and observed patterns of relations guided the selection of individual measures for aggregate measures of inattention, impulsivity and hyperactivity. Attention task and behaviour rating measures, and conceptually and statistically related parent report measures were selected for aggregation. Parent report measures were selected if their correlation with the corresponding task measure or behaviour rating measure was equal to or greater than an absolute value of .29 (based on *n*=77 completed sets of questionnaires).

These measures are those presented in Table 13. The measure of inattention were the d' score, negatively weighted to yield a measure of inattention; the examiner rating of inattention; and parent reports of nonpersistence, distractibility/hyperactivity, slow adaptability, low acceptability, and demandingness. The measures of impulsivity were the aggregate task measure; the examiner ratings of impulsivity; and parent reports of high activity level, nonpersistence, high sensory threshold, distractibility/hyperactivity, slow adaptability, low acceptability, and demandingness. The measures of hyperactivity were the examiner ratings of hyperactivity; and parent reports of high activity level, distractibility/hyperactivity, slow adaptability, low acceptability, demandingness, negative mood, and low reinforcement of the parent.

A principal components analysis, with varimax rotation, of these measures was conducted. Three factors were identified. These three factors and the factor loadings are presented in Table 14. This analysis indicated that measures obtained from the same source tended to load on the same factor. For example, most parent report measures

Table 14

Factor loadings for the attention task and behaviour measures

| | Factor I | Factor II | Factor III |
|---|---|---|---|
| Acceptability (PSI) | .78529 | .12707 | .18221 |
| Adaptability (BSQ) | .77491 | .18284 | .24364 |
| Reinforcement (PSI) | .74519 | -.12857 | -.08000 |
| Demandingness (PSI) | .72423 | .21080 | .16964 |
| Distractibility (PSI) | .69794 | .50111 | .02903 |
| Mood (PSI) | .69268 | .08823 | -.24853 |
| Nonpersistence (BSQ) | .62751 | .18551 | .40938 |
| Activity (BSQ) | .56003 | .33874 | -.15591 |
| Impulsivity rating | .07957 | .86775 | .12861 |
| Inattention rating | .11721 | .78684 | .29943 |
| Hyperactivity rating | .27928 | .73820 | -.04298 |
| Threshold (BSQ) | .03654 | .07300 | -.75174 |
| Impulsivity task score | .10703 | .31299 | .68774 |
| Inattention task score | -.09117 | .54895 | .60218 |
| Percent of variance | 38.2 | 15.8 | 9.0 |

loaded on the first factor. As method variance influenced the outcome, the principal components analysis appeared to defeat the purpose of aggregating measures obtained from different sources. Furthermore, as a principal components analysis requires complete data on each child (Norusis, 1985), the deletion of children with missing values would have resulted in a loss of statistical power and generalizability in subsequent prediction analyses.

Therefore, a Z-score approach, rather than a factor score approach, to aggregation was selected. For each aspect of attention -- inattention, impulsivity, and hyperactivity, the child's scores were transformed into Z-scores. The child's aggregate scores were the means of that child's Z-scores for each aspect. The aggregate measure of inattention was the mean of the attention task measure, the rating of inattention, and the parent report measures of nonpersistence, distractibility/hyperactivity, low adaptability, low acceptability, and demandingness. The aggregate measure of impulsivity was the mean of the task measure, the rating of impulsivity, and the parent report measures of high activity level, nonpersistence, sensory threshold (negatively weighted), distractibility/hyperactivity, low adaptability, low acceptability, and demandingness. The aggregate measure of hyperactivity was the mean of the rating of hyperactivity, and the parent report measures of high activity level, distractibility/hyperactivity, low adaptability, low acceptability, demandingness, negative mood, and low reinforcement of the parent. A summary measure of attention was also developed and retained for subsequent prediction analyses. This summary measure was the mean of the Z-scores for the task measures, the ratings, and the parent report measures selected for aggregation.

Aggregation of predictor measures.

Overview. Conceptual and statistical relations among potential predictor measures were considered and aggregate predictor measures were developed. A Z-score approach to aggregation was chosen. Predictor measures were derived from measures of immaturity/illness, socioeconomic status, the quality of the environment and infant developmental status obtained during the infant study and from measures of childhood environmental factors obtained during the current study. Separate infant and child measures of socioeconomic status and the quality of the environment were maintained. As a result, the predictive value of measures obtained during infancy for childhood development could be investigated independently and the additional predictive information provided by concurrent measures of environmental factors could be evaluated.

Expected pattern of relations among measures of medical risk and infant environmental factors. The expected pattern of relations among the measures of medical risk and environmental factors obtained during infancy are presented in Table 15. It was expected that immaturity/illness would

Table 15

Expected pattern of relations among infant medical risk and environmental measures

| Immaturity/ Illness | Socioeconomic Status | Quality of the Environment |
|---|---|---|
| Birthweight | Maternal age | 7 month HOME |
| Gestational age | Maternal education | 12 month HOME |
| Morbidity | Paternal education | 7 month Sensitivity |
| Days in hospital | Occupational status | 12 month Sensitivity |
| RDS severity | | |

be comprised of low birthweight, low gestational age, morbidity, a large number of days in hospital, and severity of RDS (respiratory distress syndrome). Two measures of environmental factors were expected. It was expected that socioeconomic status would be comprised of maternal age, maternal and paternal education, and the Blishen measure of occupational status. It was expected that the quality of the infant environment would be comprised of ratings of maternal sensitivity and scores on the infant version of the HOME Inventory, obtained at 7 and 12 months of age.

Observed pattern of relations among measures of medical risk and infant environmental factors. During the infant study, correlational and principal components analyses had been conducted on measures of medical risk and infant environmental factors obtained from the entire infant sample (Pederson et al., 1988). There had been significant intercorrelations among measures of medical risk, measures of socioeconomic status, and measures of the quality of the infant environment. Three factors had been identified as a result of the principal components analysis. These factors were immaturity/illness, socioeconomic status, and the quality of the infant environment and, thus, were consistent with the expected pattern of relations in the current study.

Correlational and principal components analyses of the measures of medical risk and environmental factors obtained for the 90 children participating in the current study were conducted. The outcome of these analyses was consistent with the analysis conducted by Pederson et al. (1988). The observed patterns of correlations and the results of the principal components analysis are presented in Appendix IV.

As expected, immaturity/illness was comprised of low birthweight, immature gestational age, high morbidity scores, a high number of days in hospital, and severe RDS; the absolute value of the intercorrelations among these measures ranged from .40 to .84. High socioeconomic status was comprised of high scores on measures of maternal age, parental education, and occupational status; these intercorrelations ranged from .35 to .67. Optimal quality of the infant environment was composed of high ratings of maternal sensitivity and high HOME Inventory scores during infancy; these intercorrelations ranged from .71 to .87.

<u>Aggregation of measures of medical risk and infant environmental factors</u>. Scores derived from these orthogonal factors could have been entered into subsequent analyses as independent predictors. The socioeconomic measure represented differences in status that may be related to cognitive outcome. The quality of the environment measure represented differences in processes that may contribute to optimal cognitive outcome. However, these two measures represent different, but related, aspects of the environment. Furthermore, determining the predictive value and relative contributions of each aspect of the environment was one purpose of subsequent analyses. Therefore, using factor scores did not seem to reflect reality or meet the

purposes of the study. Furthermore, as a principal components analyses required complete data on each child (Norusis, 1985), the deletion of children with missing values would have resulted in a loss of statistical power and generalizability in subsequent prediction analyses.

Therefore, a Z-score approach to aggregation was used. The components of these aggregate scores are those presented in Table 15. For each aggregate, the child's scores on the individual components of the aggregate were transformed into Z-scores. The child's aggregate score was the mean of that child's individual Z-scores on each construct. As birthweight and gestational age were negatively correlated with measures of illness, these two measures were negatively weighted to reflect immaturity (rather than maturity). The aggregate measure of immaturity/illness was the mean of the Z-scores for birthweight (negatively weighted), gestational age (negatively weighted), the morbidity score, the numbers of days in hospital, and the cumulative score of RDS severity. The aggregate measure of socioeconomic status was the mean of the Z-scores for maternal age, maternal education, paternal education and occupational status. The aggregate measure of the quality of the infant environment was the mean of the Z-scores for HOME Inventory scores and the ratings of maternal sensitivity obtained at 7 and 12 months.

Infant status measures. Two measures of infant status collected during the infant study were potential predictors of childhood outcome. The measures of infant developmental status were the 12-month scores on the MDI (Mental Development Index) and PDI (Psychomotor Development Index) of the Bayley Scales of Infant Development. These scores were not corrected for prematurity. The correlation between these scores was .70.

The use of either MDI or PDI scores or the use of an average of the two scores was not justified, as the scores represent measures of related, but different, aspects of infant sensorimotor development. Furthermore, the predictive value of the MDI and the PDI and their relations with environmental measures might differ. Therefore, both the MDI and the PDI were retained as potential predictor measures.

There were several reasons for using uncorrected scores, rather than scores that had been corrected for prematurity. As uncorrected scores have not been corrected for immaturity, which is strongly related to illness, the use of uncorrected scores in prediction analyses would permit a clearer understanding of the contribution of illness to subsequent outcome. Furthermore, the use of corrected scores can result in an overcorrection or inflation of the scores of very immature infants (Hunt & Rhodes, 1977). Finally, the correlations between child outcome measures and uncorrected scores tend to be more robust and more consistent than those with corrected scores.

Expected pattern of relations among childhood environmental measures. The expected pattern of relations among the multiple measures of socioeconomic status and the quality of the environment during childhood are presented in Table 16. It was expected that a measure of socioeconomic status would be comprised of high scores on measures of maternal education, paternal education, occupational status and income category. It was expected that a measure of the quality of the child environment would be comprised of high scores on the HOME Inventory and, for children whose mothers had completed the Peabody Picture Vocabulary Test, high scores on the maternal vocabulary measure.

Observed pattern of relations among childhood environmental measures. A correlational analyses was conducted to determine the observed pattern of relations. These data are presented in Table 17. This observed pattern was consistent with the expected pattern. As expected, there were significant statistical relations among measures of socioeconomic status and among measures of the quality of the child environment. There were also correlations between measures of socioeconomic status and measures of the quality of the child environment. The HOME Inventory score was positively correlated with socioeconomic status. As might be expected, maternal vocabulary was strongly related to both maternal education and the HOME inventory score.

Aggregation of child environmental measures. A principal components analysis, with varimax rotation, of the

Table 16

Expected pattern of relations among child environmental measures

| Socioeconomic Status | Quality of the Environment |
|---|---|
| Maternal education | 5 year HOME |
| Paternal education | Maternal vocabulary |
| Occupational status | |
| Income | |

Table 17

Intercorrelations among child environmental measures

| Measure | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Socioeconomic status | | | | | |
| 1. Maternal education | .64[a] | .47[b] | .32[c] | .29[a] | .44[d] |
| 2. Paternal education | | .64[e] | .35[c] | .36[f] | .44[d] |
| 3. Occupational status | | | .27[c] | .26[a] | .27[d] |
| 4. Income | | | | .26[g] | .14[d] |
| Quality of the environment | | | | | |
| 5. 5 year HOME | | | | | .41[h] |
| 6. Maternal vocabulary | | | | | |

[a] *n*=86. [b] *n*=89. [c] *n*=88. [d] *n*=58. [e] *n*=87. [f] *n*=84. [g] *n*=85. [h] *n*=57.
For $n = 84$, correlation coefficients ($r$) with an absolute value of .28 or greater are significantly different from 0 at $p<.005$.

measures of environmental factors was conducted. The child measures of socioeconomic status were maternal and paternal education, the Blishen score, and income. The measures of the quality of the child environment were the preschool HOME Inventory score and the maternal vocabulary score.

Two factors were identified as a result of the principal components analysis. These two factors and the factor loadings for each measure are presented in Table 18. The outcome of the principal components analysis was consistent with the expected pattern of relations among the measures of environmental factors. As a principal components analysis requires complete data on each child (Norusis, 1985), the deletion of children with missing values on the maternal vocabulary score would have reduced the sample size to 58, resulting in a loss of statistical power and generalizability in subsequent prediction analyses.

Therefore, a Z-score approach was selected as an approach to aggregation. The child's scores were transformed into Z-scores. The aggregate measure of child socioeconomic status was the mean of the Z-scores for maternal education, paternal education, occupational status and income category. The Z-score for HOME Inventory score was designated as the measure of the quality of the child environment. Prediction analyses that also considered maternal vocabulary as a predictor of child outcome could be conducted separately.

Table 18

Factor loadings for childhood predictor measures

| Measure | Factor 1 | Factor 2 |
|---|---|---|
| Occupational status | .80835 | -.01529 |
| Paternal education | .77019 | .38965 |
| Maternal education | .74622 | .36266 |
| Income | .68379 | .08648 |
| 5 year HOME | .07271 | .81177 |
| Maternal vocabulary | .21504 | .78586 |
| Percent of variance | 47.9 | 17.0 |

Prediction of childhood outcomes.

Overview. The purpose of prediction analyses was to predict specific childhood outcomes from infant and concurrent measures. Potential predictors from infancy were aggregate measures of infant immaturity/illness, the quality of the infant environment and infant socioeconomic status; and two measures of infant status -- the 12-month MDI and PDI scores of the Bayley Scales of Infant Development. Potential concurrent predictors were the quality of the child environment (HOME Inventory score) and the aggregate measure of child socioeconomic status.

The choice of an approach to prediction was governed by the nature of the data set, the nature of the research questions, and the conceptual framework guiding the research. The data set included continuous aggregate measures of factors that may predict outcome among low birthweight children. These aggregates would be less likely to yield results influenced by sample-specific characteristics and correlations than individual measures. The research questions included an interest in the predictive value of infant measures and in the predictive value of concurrent environmental factors relative to these infant measures. The conceptual framework guiding the research required a consideration of the predictive value of both infant characteristics (immaturity/illness, developmental status) and environmental factors (socioeconomic status, the quality of the environment) to specific childhood outcome.

Stepwise multiple regression analyses were chosen as the approach to prediction. The regression approach was suitable for a data set consisting of continuous measures. Furthermore, the predictive value of infant measures could first be considered. Then, the predictive utility of these measures relative to concurrent environmental measures could then be considered. Finally, this approach was appropriate for research questions that included an interest in the contribution of both child characteristics and environmental factors to developmental outcome. Stepwise multiple regression would allow the contribution of each predictor to be re-evaluated following the stepwise addition of a new predictor to the analysis and would also provide a basis for subsequent explanation analyses.

# Results

*Overview.* The purpose of these analyses was to evaluate and compare the predictive utility of medical risk, infant developmental status and environmental factors for specific childhood outcomes. The predictor measures were entered into a series of stepwise multiple regression analyses. The outcome measures for these analyses were measures of global cognitive, language, motor, and attention outcome. For each outcome, three sets of stepwise multiple regression analyses were conducted. First, the aggregate measures of infant immaturity/illness, the quality of the infant environment, and infant socioeconomic status were entered as predictors. Next, measures of infant developmental status were entered into the analysis. Finally, all potential predictors were entered into the regression analyses. A separate supplementary analyses was conducted in order to consider the contribution of maternal vocabulary to childhood outcome. The best prediction equations for childhood global cognitive, language, motor and attention outcomes were then presented.

*Intercorrelations among predictor measures.* A correlational analysis of the potential predictor measures was conducted prior to subsequent regression analyses. These data are presented in Table 19.

Among infant predictor measures, immaturity /illness (IMMILL) was negatively correlated with Bayley MDI and PDI scores, but not significantly correlated with either

Table 19

Intercorrelations of predictor measures (n=90)

| Measure | 2 | 3 | 4 | 5 | 6[a] | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 1. IMMILL | .01 | -.21 | -.53 | -.47 | .09 | -.23 | -.31 |
| 2. INFENV | | .56 | .31 | .29 | .60 | .53 | .27 |
| 3. INFSES | | | .23 | .12 | .49 | .88 | .50 |
| 4. MDI | | | | .70 | .26 | .21 | .21 |
| 5. PDI | | | | | .15 | .08 | .12 |
| 6. CHENV | | | | | | .38 | .41 |
| 7. CHSES | | | | | | | .43 |
| 8. MATVOCAB | | | | | | | |

[a] $n = 87$.

For $n = 87$, correlation coefficients with an absolute value of .27 or greater are significantly different from 0 at $p<.005$.

Note: IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV=Total HOME Inventory score, early childhood version; CHSES=Aggregate measure of childhood socioeconomic status; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

socioeconomic status (INFSES) or the quality of the environment (INFENV). The quality of the environment was positively correlated with socioeconomic status and MDI and PDI scores. Socioeconomic status was not correlated with either MDI or PDI scores.

Among child measures, socioeconomic status (CHSES) was significantly related to both the quality of the environment (CHENV) and maternal vocabulary (MATVOCAB), which were correlated. Finally, there were strong relations between infant and child measures of socioeconomic status and quality of the environment.

Correlations between predictor and outcome measures. A correlational analysis of the potential predictor measures and the child outcome measures was conducted prior to subsequent regression analyses. These data are presented in Table 20. Potential predictors from infancy were aggregate measures of infant immaturity/illness (IMMILL); the quality of the infant environment (INFENV); infant socioeconomic status (INFSES); and the uncorrected Mental Development Index (MDI) and Psychomotor Development Index (PDI) scores of the Bayley Scales. Potential concurrent predictors were the quality of the child environment, the HOME Inventory score (CHENV) and the aggregate measure of child socioeconomic status (CHSES). Maternal vocabulary (MATPPVT) was also a concurrent predictor, but was considered in separate prediction analyses.

Table 20

Correlations between predictor and outcome measures (n=88)

| | Infant Factors | | |
|---|---|---|---|
| Outcome | IMMILL | INFSES | INFENV |
| GCI | -.28 | .31 | .27 |
| Language | -.18 | .36 | .34 |
| Motor[a] | -.31 | .01 | .09 |
| Inattention | .13 | -.09 | -.25 |
| Impulsivity | .07 | -.08 | -.28 |
| Hyperactivity | .07 | -.14 | -.23 |

| | Infant Status | |
|---|---|---|
| Outcome | MDI | PDI |
| GCI | .55 | .34 |
| Language | .48 | .32 |
| Motor[a] | .44 | .38 |
| Inattention | -.39 | -.34 |
| Impulsivity | -.34 | -.28 |
| Hyperactivity | -.20 | -.23 |

Table 20, cont'd.

Correlations between predictor and outcome measures (n=.8)

| | Concurrent Factors | | |
|---|---|---|---|
| Outcome | CHSES | CHENV[b] | MATVOCAB[c] |
| GCI | .28 | .38 | .30 |
| Language | .33 | .42[d] | .48 |
| Motor | .06[e] | .13 | -.09 |
| Inattention | .02 | -.29[d] | -.10 |
| Impulsivity | -.07 | -.30 | -.08 |
| Hyperactivity | -.01 | -.32 | -.11 |

[a] n = 90. [b] n = 85. [c] n = 58. [d] n = 86. [e] n = 83. [f] n = 57.

For n = 83, correlation coefficients with an absolute value of .28 or greater are significantly different from 0 at p<.005.

Note: IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV=Total HOME Inventory score, early childhood version; CHSES=Aggregate measure of childhood socioeconomic status; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

The patterns of statistical relations between child outcome measures and infant predictors varied for different child outcomes. Immaturity/illness was more strongly related to motor outcome than to language outcome. Similarly, whereas infant socioeconomic status was related to global cognitive outcomes, the quality of the infant environment was related to these and to attention outcomes. The Bayley MDI and PDI were significantly correlated with most childhood outcome measures. Finally, the pattern of relations between child outcomes and measures of infant environmental factors was similar to that with measures of child environmental factors. The magnitude of the correlations between childhood outcome and the quality of the child environment tended to be greater than those with measures of the quality of the infant environment.

<u>The prediction of child outcomes from infant measures of immaturity/illness, socioeconomic status and the quality of the environment</u>. First, in order to consider the contribution of infant factors to subsequent development, the aggregate measures of infant immaturity/illness, the quality of the infant environment, and infant socioeconomic status were entered as potential predictors in the regression analyses. A separate stepwise multiple regression analysis was conducted for each outcome measure. The outcome measures were measures of global cognitive (GCI), language (LANG), and motor (MOTOR) outcomes; and inattention (INATT), impulsivity (IMPULS), hyperactivity

(HYPER). Therefore, 6 stepwise multiple regression analyses were conducted with measures of infant immaturity, the quality of the infant environment and infant socioeconomic status entered as potential predictors. A predictor measure was entered in the regression equation if the probability associated with the F test for the significance of the regression coefficient was less than or equal to 0.05.

The results of these regression analyses are summarized in Table 21. As expected, the best prediction equation differed for different childhood outcomes. Infant socioeconomic status and immaturity/illness were both significant predictors of global cognitive outcome. Infant socioeconomic status was the only significant predictor of child language outcome. Infant immaturity/illness was the only significant predictor of child motor outcome. The quality of the infant environment was the only significant predictor of child inattention, impulsivity, and hyperactivity. These data also indicated that the proportion of variance in child outcomes accounted for by immaturity/illness, socioeconomic status and the quality of the infant environment was relatively small. $R^2$'s ranged from .04 to .12.

<u>The contribution of 12-month status to the prediction of child outcomes.</u> Next, in order to consider the contribution of infant developmental status at 12 months to child outcome, Bayley MDI and PDI scores were entered into the prediction analysis, along with the aggregate measures

Table 21

Prediction of childhood outcomes from infant factors (IMMILL, INFENV, INFSES)

| Outcome | Predictors | R | $R^2$ | Adj$R^{2a}$ | Overall F(df) |
|---|---|---|---|---|---|
| GCI | INFSES, IMMILL | .38 | .14 | .12 | 7.13** (2,85) |
| LANG | INFSES | .36 | .13 | .12 | 12.98** (1,88) |
| MOTOR | IMMILL | .31 | .09 | .08 | 8.92* (1,88) |
| INATT | INFENV | .25 | .06 | .05 | 5.61* (1,86) |
| IMPULS | INFENV | .27 | .08 | .06 | 7.02* (1,86) |
| HYPER | INFENV | .23 | .05 | .04 | 4.72+ (1,86) |

[a] Adjusted $R^2$. + $p<.05$. * $p<.01$. ** $p<.001$.

of infant immaturity/illness, the quality of the infant environment, and infant socioeconomic status. A separate stepwise multiple regression analysis was conducted for each outcome measure. Therefore, 6 stepwise multiple regression analyses were conducted.

The results of these regression analyses are summarized in Table 22. These analyses indicated once again that the best prediction equation differed for different childhood outcomes. Furthermore, the MDI score was selected as a predictor of nearly all childhood outcomes. Both MDI and infant socioeconomic status were significant predictors of global cognitive and language outcomes. The MDI score was the only significant predictor of motor, inattention and impulsivity outcome measures. The quality of the infant environment was the only significant predictor of hyperactivity. The proportion of variance accounted for by immaturity/illness, socioeconomic status, the quality of the infant environment and measures of infant developmental status was variable. $R^2$'s ranged from .04 to .32.

The contribution of child measures of socioeconomic status and quality of the environment to the prediction of child outcomes. Finally, to consider the contribution of concurrent environmental factors to child outcome, aggregate measures of the quality of the child environment and child socioeconomic status were entered into the prediction analyses, along with the aggregate measures of infant immaturity/illness, the quality of the infant environment,

Table 22

Prediction of childhood outcomes from infant factors (IMMILL, INFENV, INFSES) and developmental status (MDI, PDI)

| Outcome | Predictors | R | $R^2$ | $AdjR^{2a}$ | Overall F | (df) |
|---|---|---|---|---|---|---|
| GCI | MDI, INFSES | .58 | .34 | .32 | 21.83** | (2,85) |
| LANG | MDI, INFSES | .54 | .30 | .28 | 18.35** | (2,87) |
| MOTOR | MDI | .44 | .19 | .18 | 20.88** | (1,88) |
| INATT | MDI | .39 | .15 | .14 | 15.16** | (1,86) |
| IMPULS | MDI | .34 | .11 | .10 | 11.12* | (1,86) |
| HYPER | INFENV | .23 | .05 | .04 | 4.72* | (1,86) |

[a] Adjusted $R^2$. [+] $p<.05$. * $p<.01$. ** $p<.001$.

infant socioeconomic status, and Bayley MDI and PDI scores. A separate stepwise multiple regression analysis was conducted for each outcome measure. Therefore, 6 stepwise multiple regression analyses were conducted.

The results of these regression analyses are summarized in Table 23. These analyses indicated that the best prediction equation differed for different childhood outcomes. Furthermore, the quality of the child environment was a significant predictor of 3 of the 6 child outcome measures. Both the MDI score and the quality of the child environment were significant predictors of global cognitive, and language outcomes, and of the impulsivity outcome measure. The MDI score was retained as the only significant predictor of motor and inattention outcomes. The quality of the child environment was the only significant predictor of hyperactivity. The proportion of variance in child outcomes accounted for ranged from .09 to .35.

The contribution of maternal vocabulary to the prediction of child outcomes. For children for whom both a HOME score and a maternal vocabulary score had been obtained, a separate stepwise multiple regression analysis was conducted for each outcome measure. Maternal vocabulary score was entered into the prediction analysis, along with all of the other predictors. Therefore, 6 stepwise multiple regression analyses were conducted.

The results of these regression analyses are summarized in Table 24. These analyses indicated that maternal

Table 23

Prediction of childhood outcomes from infant factors, developmental status, and concurrent factors (CHENV, CHSES)

| Outcome | Predictors | R | $R^2$ | Adj$R^{2a}$ | Overall F(df) |
|---|---|---|---|---|---|
| GCI | MDI, CHENV | .60 | .36 | .35 | 23.28** (2,82) |
| LANG | MDI, CHENV | .57 | .32 | .31 | 19.82** (2,83) |
| MOTOR | MDI | .44 | .19 | .18 | 19.93** (1,84) |
| INATT | MDI | .39 | .15 | .14 | 14.81** (1,84) |
| IMPULS | MDI, CHENV | .41 | .16 | .14 | 8.12** (2,83) |
| HYPER | CHENV | .32 | .10 | .09 | 9.17* (1,84) |

[a] Adjusted $R^2$. + $p<.05$. * $p<.01$. ** $p<.001$.

Table 24

Prediction of childhood outcomes from infant factors, developmental status, concurrent factors and maternal vocabulary (MATVOCAB)

| Outcome | Predictors | R | $R^2$ | $AdjR^{2a}$ | Overall F(df) |
|---|---|---|---|---|---|
| GCI | MDI, CHENV | .60 | .36 | .35 | 15.33** (2,54) |
| LANG | MATVOCAB, MDI | .62 | .38 | .36 | 16.76** (2,54) |
| MOTOR | MDI | .44 | .19 | .18 | 13.05** (1,55) |
| INATT | MDI | .39 | .15 | .13 | 9.70* (1,55) |
| IMPULS | MDI | .34 | .11 | .10 | 7.11* (1,55) |
| HYPER | CHENV | .32 | .10 | .09 | 6.36+ (1,55) |

[a] Adjusted $R^2$. + $p<.05$. * $p<.01$. ** $p<.001$.

vocabulary was a significant predictor of language outcome only. Maternal vocabulary and MDI score were significant predictors of language outcome and the HOME score was deleted as a signficant predictor of this child outcome. The best prediction equations for global cognitive, motor and attention outcomes remained the same as in the prediction analyses that included only the HOME score as a measure of the quality of the child environment.

The deletion of the HOME score as a significant predictor was no doubt influenced by its relation to maternal vocabulary. This interpretation was supported by the deletion of HOME scores as a significant predictors of impulsivity. The increase in the number of measures of the quality of the child environment entered into the prediction analysis appeared to have resulted in a different, lower estimate of the regression coefficient for the HOME score. Consequently, the HOME score was no longer selected as a significant predictor of language outcome or of impulsivity.

The best prediction equations for child outcomes. The best prediction equation for each of the child outcomes are presented in Table 25. These analyses demonstrated, as expected, that the significant predictors of child outcome differed for different outcomes. Although it was possible to predict child outcome in different domains of development from infant immaturity/illness, socioeconomic status, and the quality of the infant environment, a measure of infant developmental status at 12 months was a significant

Table 25

The best prediction equations for childhood outcomes

| Outcome | R | $R^{2a}$ | F (df) |
|---|---|---|---|
| GCI = .00 + .49MDI + .25CHENV | .60 | .35 | 23.82** (2,82) |
| LANG =-.04 + .37MDI + .30CHENV | .57 | .31 | 19.83** (2,83) |
| LANG = .04 + .38MATVOCAB + .37MDI | .62 | .36 | 16.76** (2,54) |
| MOTOR = .00 + .49MDI | .44 | .19 | 19.93** (1,84) |
| INATT = .03 - .31MDI | .39 | .14 | 14.81** (1,84) |
| IMPULS= .05 - .17MDI -.14CHENV | .40 | .14 | 8.12** (2,83) |
| HYPE = .05 - .23CHENV | .32 | .10 | 9.71* (1,84) |

[a] Adjusted $R^2$. * $p < .01$. ** $p < .001$.

predictor of most outcomes when it was entered into the analyses. A measure of the quality of the child environment was a significant predictor of global cognitive and and language outcomes, and of impulsivity; child socioeconomic status was not selected as a significant predictor of child outcome in any domain of development. An additional measure of the quality of the child environment, maternal vocabulary, was a significant predictor of language outcome.

Although the same set of predictors may have been selected for several different outcomes, the value of the regression coefficients were not the same in each equation. This suggested, for example, that both infant developmental status and the quality of the child environment may be important factors in several domains of development, but that the contribution of each factor may be different for each outcome measure. However, this suggestion cannot be supported on the basis of the regression coefficients alone (Pedhazur, 1982). Rather, statements concerning the the relative contribution of each predictor to a specific child outcome could be supported most clearly by the results of subsequent explanation analyses.

## Discussion

The results of these analyses support several conclusions concerning the relation between low birthweight and subsequent development. First, immaturity/illness alone cannot account for the variability in outcome, as environmental factors must also be considered in prediction. Second, the influence of either immaturity/illness or environmental factors on subsequent outcome may vary for different developmental outcomes.

Global cognitive outcome. As the literature summarized in the introduction suggests, medical risk, socioeconomic status and the quality of the environment during infancy have some predictive value for global cognitive outcome, and measures of environmental factors are more consistently and strongly correlated with outcome than are measures of medical risk (Aylward et al., 1989; Gottfried, 1984). Multivariate approaches to prediction summarized in the introduction suggest that some combination of measures of medical risk, environmental factors, and infant developmental status will predict global cognitive outcome during early childhood. The results of the current study support these expectations.

As expected, the McCarthy GCI is negatively correlated with immaturity/illness and positively correlated with socioeconomic status during infancy, and the correlation with the quality of the infant environment approaches significance. These results are consistent with the findings of several investigations of the relation between global cognitive outcome and medical risk (Klein et al., 1985; Largo, 1987; Siegel, 1982; Williams et al., 1987), and infant environmental factors such as parental education, socioeconomic status (Cohen & Parmalee, 1983; Crisafi et al., 1989; Hunt, 1981; Klein et al., 1985; Largo, 1987; Rose & Wallace, 1985; Siegel, 1984a; Wallace et al., 1982), or the quality of the infant's physical and social environment (Beckwith & Cohen, 1984; Siegel, 1984a). Therefore, the influence of medical risk on subsequent functioning cannot be considered apart from the influence of infant environmental factors (Aylward et al., 1989; Cohen, 1986; Sameroff & Chandler, 1975). The GCI is also positively correlated with Bayley scores, a finding that is consistent with the results of several recent studies that have used either the MCarthy GCI or IQ scores (Astbury et al., 1990; Barrera & Kitching, 1990; Cohen & Parmalee, 1983; Hunt, 1981; Largo et al., 1990; McDonald et al., 1989; O'Connor et al., 1984; Ross et al., 1985; Siegel, 1982; Williams et al., 1987), and supports the predictive validity of such measures among low birthweight children. Finally, there are significant correlations between the GCI and both socioeconomic status and the quality of the home environment during childhood, although the quality of the child environment is more strongly related to GCI than is socioeconomic status during childhood. These findings are consistent with reports of the importance of concurrent environmental factors to cognitive functioning during childhood (Siegel, 1984) and support the utility of obtaining both status and process measures of environmental factors.

Multiple regression analyses indicate that, among infant factors, socioeconomic status and immaturity/illness are significant predictors of the GCI. When the Bayley MDI and PDI scores are entered into the regression analysis, the Bayley MDI and socioeconomic status during infancy are significant predictors of the GCI. These analyses indicate that, although it is possible to predict early childhood global cognitive outcome on the basis of infant factors (immaturity/illness and socioeconomic status) alone, a measure of infant developmental status improves prediction. Furthermore, although medical risk is related to subsequent outcome, its influence may be reflected indirectly by infant developmental scores. These findings are consistent with the results of previous research. For example, Siegel (1982) reported that both environmental and medical risk measures were significant predictors of the GCI, and that the Bayley MDI score significantly improved the accuracy of prediction. The contribution of both socioeconomic status and infant developmental test scores to the prediction of global cognitive outcome has also reported in several other studies (Cohen & Parmalee, 1983; Crisafi et al., 1987; Ross et al., 1985).

Although a few studies have reported that the quality of the infant environment predicts subsequent global cognitive outcome (Beckwith & Cohen 1984; Cohen & Parmalee, 1983; Siegel, 1982, 1984), the results of the current study indicate, rather, that socioeconomic status during infancy is a significant predictor of the GCI. This discrepancy may be due, in part, to the fact that the correlation between GCI and socioeconomic status is slightly greater than the correlation between GCI and the quality of the environment during infancy. Therefore, in the stepwise multiple regression analysis, socioeconomic status is selected as a significant predictor. In addition, infant socioeconomic status is related to both the quality of the infant environment and the Bayley MDI, that are also correlated. Therefore, the contribution of the quality of the infant environment may be indirectly expressed through the MDI and socioeconomic status.

The predictive value of infant test scores may be due to either statistical factors or to processes that are continuous between infancy and childhood. One relevant statistical factor may be the wide range of scores obtained in the current study, as uncorrected Bayley MDI scores ranged from 56 to 147; McCarthy GCI scores ranged from 56 to 130. A comparison of the Small/Ill and Large/Well subgroups also indicates considerable variability within each subgroup, although children in the Small/Ill group tended to have lower scores during infancy. Uncorrected Bayley MDI scores ranged from 56 to 131 and from 74 to 147 for the Small/Ill and Large/Well subgroups respectively. McCarthy GCI scores ranged from 56 to 130 and from 57 to 130 for the Small/Ill and Large/Well subgroups respectively. These findings are consistent with reports of greater variability in test scores among low birthweight samples (McDonald et al., 1989; Portnoy et al., 1988; Ross, 1989).

This greater variability relative to the normal population has been thought to contribute to the greater predictive validity of measures of infant developmental status among high risk populations (McDonald et al., 1989; Ross, 1989). Studies that have compared the magnitude of correlations between infant and childhood test scores for low birthweight and normal birthweight samples have provided inconsistent reports of such group differences. There have been some reports of significantly larger correlations between infant and childhood scores among low birthweight samples (Largo et al., 1990; McDonald et al., 1989), as well as reports of nonsignificant differences in the magnitude of correlations despite greater variability among low birthweight children (Portnoy et al., 1988). There are few reports of such differences between subgroups within a low birthweight sample. A comparison of the correlations for the Small/Ill ($\underline{n}$=63) and Large/Well ($\underline{n}$=27) subgroups indicates a lower correlation for the Small/Ill than for the Large/Well group, as significant correlations between uncorrected Bayley MDI and McCarthy GCI were .44 and .72 for the Small/Ill and Large/Well groups respectively. Therefore, there is substantial consistency of relative status within each subgroup, but greater medical risk is associated with less, rather than more, consistency between infancy and early childhood.

An additional statistical factor is that low birthweight may increase the risk for poor performance (Aylward et al., 1989), influencing the distribution of scores on measures of global cognitive outcome. As there are reports of a greater stability among children with low scores (Sameroff & Chandler, 1975), this may contribute to the consistency of relative status and, therefore, to the magnitude of the correlation between infant and early childhood test scores. An examination of the distribution of GCI scores in the current study indicates that 21% of the children obtained uncorrected Bayley MDIs that were less than 90; 27% obtained McCarthy GCIs that were less than 90; and 13% obtained scores that were less than 90 during both infancy and childhood. Sixty-one percent of the children with MDIs less than 90 also obtained GCI scores less than 90. These percentages do not suggest either an increased risk for low scores relative to the normal population or a greater degree of stability among low scoring children.

Apart from possible statistical factors, the relation between infant developmental scores and global cognitive outcome measures may be influenced by cognitive or attentional processes that are continuous between infancy and early childhood. For example, Siegel (1979) proposed that significant relations between the Bayley and the McCarthy may be due to underlying cognitive and motoric processes that are assessed by each measure. Similarly, Astbury et al. (1987) reported that ratings of attention during infant developmental testing are predictive of global cognitive outcome during early childhood. In the current study, the correlations between the Bayley scores and the GCI lend support to this explanation. For example, the GCI is more strongly related to the MDI than to the PDI, suggesting some continuity in either underlying cognitive processes (language development for example) or attention processes (sustained attention during challenging cognitive tasks, for example).

When childhood measures of socioeconomic status and the quality of the environment are entered into the analysis, the MDI and the quality of the environment are significant predictors of the GCI. Therefore, although socioeconomic status during infancy predicts GCI, it is no longer a significant predictor when the quality of the child environment is entered into the prediction analysis. This finding is consistent with the suggestion that concurrent environmental factors are important influences on childhood outcome (Gottfried, 1984; Sameroff & Chandler, 1975), reflecting the more powerful effect of a proximal environmental factor relative to a distal environmental factor (Gottfried, 1984). Furthermore, as the quality of the child environment is correlated with both socioeconomic status during infancy and the quality of the infant environment, the contribution of infant environmental factors to the prediction of the GCI may be expressed indirectly.

Specific childhood outcomes

Language outcome. The correlational analyses indicate that childhood language outcome is positively correlated with infant socioeconomic status and the quality of the infant environment, a finding that is consistent with a number of studies that have reported correlations between child language and measures of parent education (Largo et al., 1987; Rose & Wallace, 1985b), socioeconomic status (Siegel, 1984; Wallace et al., 1982), and 'he quality of the infant environment (Siegel, 1984). Language outcome is also correlated with Bayley scores, a result that is consistent with other reports of language outcome (Ross et al., 1985b; Siegel, 1982). There were also significant correlations between the language outcome measure and all three concurrent environmental factors -- childhood socioeconomic status, the quality of the child environment, and maternal vocabulary.

As expected, infant developmental status and the quality of the environment predict language outcome. The multiple regression analyses indicate that, although it is possible to predict early childhood language outcome on the basis of socioeconomic status during infancy alone, a measure of infant status and a concurrent measure of the quality of the environment yield the best prediction equation. Among infant factors, socioeconomic status is a significant predictor of language outcome. When the Bayley MDI and PDI scores are entered into the regression analysis, the Bayley MDI and infant socioeconomic status are significant predictors of childhood language. When the concurrent predictors are entered into the analysis, the MDI and maternal vocabulary are significant predictors of language outcome.

Among infant factors, environmental factors, rather than medical risk, are important predictors of childhood language outcome and may have both direct and indirect effects. The relation between the MDI and language outcome may be influenced by the fact that both measures are correlated with environmental measures. Alternatively, the MDI score may reflect aspects of infant functioning that are relevant to and predictive of subsequent language development. For example, at 12 months, the Bayley includes numerous items that tap early imitation and language skills. As language outcome is more strongly related to the MDI than to the PDI, this result also supports the utility of maintaining both scores as separate measures of different aspects of infant functioning. Furthermore, specific aspects of the quality of the child environment, such as maternal vocabulary, may be most important to childhood language development, suggesting that qualitative aspects of the child environment, rather than socioeconomic status alone, may be important to childhood language functioning.

Motor outcome. The correlational analyses indicate that immaturity/illness is negatively correlated with childhood motor skills, and there are no significant correlations between motor outcome and infant socioeconomic status and the quality of the infant environment. These findings are consistent with the results of studies that report a relation between childhood motor outcome and measures of medical risk (Klein et al., 1985; Lindahl, 1987; Marlow et al., 1989; Williams et al., 1987), and no relation with infant environmental factors (Siegel, 1984), although there have been occasional reports of modest correlations between measures of socioeconomic status and visual-motor skills (Klein et al., 1985). Motor outcome is significantly correlated with the Bayley MDI and PDI scores, a result that is consistent with a limited number of earlier reports (Siegel, 1983; 1984).

As expected, immaturity/illness and infant developmental status predict motor outcome. Multiple regression analyses indicate that, although it is possible to predict early childhood motor outcome on the basis of infant medical risk alone, a measure of infant status yields the best prediction equation. Among infant factors, immaturity/illness is a significant predictor. When the Bayley MDI and PDI scores are entered into the analysis, the Bayley MDI is the only significant predictor, and continues to be the only significant predictor when childhood environmental measures are entered into the analysis.

These results complement the limited number of studies that have considered multivariate approaches to the prediction of motor outcome, although the results of the current study are not completely consistent with past research. The predictive utility of immaturity/illness is consistent with Siegel's report (1982, 1983) that measures of medical risk were more likely to be significant predictors of the McCarthy Motor scale score than are measures of demographic factors. However, Crisafi et al. (1987) reported that a measure of socioeconomic status, rather than an aggregate measure of illness, was a significant predictor of the McCarthy Motor scale. These discrepant findings suggest that both biological and environmental factors may be reflected in measures of socioeconomic status. Furthermore, differences among samples in the relation between low birthweight and poor environmental conditions may contribute to the pattern of findings. The nonsignificant correlation between immaturity/illness and socioeconomic status in the current study support this interpretation. Although Siegel (1982, 1983) reported that 12-month Bayley scores did not significantly increase the multiple R for the motor outcome measure beyond the contribution of medical risk, the predictive value of measures of infant development is supported in the current study. The magnitude of the correlation between the PDI score and motor outcome is greater than the correlation between the PDI and any other outcome measure, and is suggestive of continuity in relative level of motor development. Although the magnitude of the correlation between motor outcome and MDI is greater than its correlation with PDI, this may be due to the fact that the level of psychomotor development at 12 months will also influence performance on the mental scale, as success on a number of the mental scale items requires the controlled release and manipulation of small blocks and other toys.

Attention outcome. There are no significant correlations between either immaturity/illness or infant socioeconomic status and inattention, impulsivity, and hyperactivity, although there are different patterns of correlations between the other potential predictors and the three aspects of attention. Inattention is negatively correlated with Bayley MDI and PDI scores and the quality of the child environment, and the correlation with the quality of the infant environment approaches significance. Impulsivity is negatively correlated with Bayley MDI and PDI scores, and the correlation with the quality of the infant environment approaches significance. Hyperactivity is negatively correlated with the quality of the child environment, and the correlation with the Bayley PDI score approaches significance. These findings are consistent with past reports of the relation between infant developmental status and different aspects of childhood attention outcome (Astbury et al., 1987; Siegel, 1983).

As expected, both infant developmental status and the quality of the environment predict attention outcomes. Multiple regression analyses indicate that, although it is possible to predict early childhood inattention, impulsivity and hyperactivity on the basis of the quality of the infant environment, measures of infant status and a concurrent measure of the quality of the environment yield the best prediction equation. Among infant factors, the quality of the infant environment is a significant predictor of inattention, impulsivity and hyperactivity. When the Bayley MDI and PDI scores are entered into the regression analysis, the Bayley MDI is a significant predictor of both inattention and impulsivity. When concurrent environmental factors are entered into the analysis, the MDI is a significant predictor of inattention; the MDI and the quality of the child environment are significant predictors of impulsivity; and the quality of the child environment is a significant predictor of hyperactivity.

These results support several conclusions concerning the prediction of attention outcome among low birthweight children. The utility of a multidimensional assessment of attention problems is supported, as there are different patterns of correlations between predictors and the three aspects of attention. Although the variance accounted for by the various measures of infant factors is not great, the correlations are suggestive of some continuity in the different aspects of attentional development. The Bayley MDI, a measure that would presumably be influenced by individual differences in sustained attention and task persistence, is a predictor of childhood inattention. The Bayley PDI, a measure that would presumably reflect individual differences in motor development, tends to be related to childhood hyperactivity. Furthermore, the quality of the environment during infancy and childhood is also consistently related to both impulsivity and hyperactivity. This suggests that the quality of the social environment may make an important contribution to the development of attention problems.

Implications of prediction analyses

The results of these analyses suggest two conclusions relevant to the effort to understand the consequences of low birthweight, and are also suggestive of underlying models of the development of low birthweight children. First, multiple predictors -- both medical risk and environmental factors -- must be considered in the prediction of outcome among low birthweight children. Second, the influences of medical risk and environmental factors on subsequent outcome may vary for different developmental outcomes. These conclusions are supported in various recent reviews of the low birthweight literature (Aylward et al., 1989; Hunt, 1986; Murphy et al., 1982) and are suggestive of processes underlying different domains of development. Therefore, the prediction analyses also have implications for possible causal models of the development of low birthweight children, suggesting the likelihood of multivariate models that may differ for different aspects of functioning.

Multiple predictors of outcome. The conclusion that multiple factors must be considered in order to account for developmental outcome among high risk children was perhaps most eloquently stated in Sameroff and Chandler's (1975) classic chapter concerning models of development among high risk populations. Sameroff and Chandler considered the problem of "predictive inefficiency" to be a consequence of an exclusive focus on either child or environmental factors, and based on an assumption of a linear relation between either of these predictors and subsequent outcome -- a model of development that is inadequate in accounting for the wide variation in outcome observed in prospective studies of high risk groups (Sameroff & Chandler, 1975).

This conclusion is certainly suggested by the existing low birthweight research literature and is supported by the results of the current study. Nonetheless, a linear or main effects model of development appears to underlie a substantial proportion of recent studies, but is accompanied by difficulties in causal interpretation. These difficulties are evident in descriptive research, that appears to infer a causal influence of early medical risk from group differences, and in the prospective examination of group differences, as assignment to a low birthweight group is nonrandom, and the relation between birthweight and subsequent outcome may be the consequence of intervening variables such as accompanying medical risks or the home environment (Sameroff & Chandler, 1975). Research that focuses on any single measure -- medical risk, environmental factors, or infant developmental status -- as a means of identifying the low birthweight infants who will be at continued risk for developmental problems is also based implicitly on a linear model.

In contrast to a linear model, Sameroff and Chandler (1975) proposed a transactional model of development, that considers multiple factors and mutual influences of child factors and environmental factors in the prediction of developmental outcome. Predictive inefficiency is the consequence, not of the failure to correctly identify a single factor that will successfully predict outcome, but of a lack of information concerning multiple influences. With respect to children who have experienced early medical risk, the predictive validity of biological factors can only be ascertained by considering aspects of the caretaking environment. In contrast to a linear model, that proposes a single, direct causal relation between early medical risk and subsequent outcome, a transactional model proposes both direct and indirect relations or paths between early medical risk and later outcome and allows one to emphasize the contribution, rather than the causal role, of medical risk to subsequent outcome (Murphy et al., 1982; Sameroff & Chandler, 1975).

The wisdom of considering a transactional model is supported by the results of the current study. For example, correlational analyses indicate that immaturity/illness accounts for between .01 (impulsivity and hyperactivity) and .10 (motor outcome) of the variance in childhood outcomes. Alternatively, infant environmental factors accounts for between .00 (motor outcome) and .13 (language) of the variance in these outcomes. However, multivariate prediction analyses indicate that variance accounted for increases as infant environmental factors, infant developmental status, and child environmental factors are considered. These results support Sameroff and Chandler's conclusion (1975) that the solution to the problem of predictive efficiency is to consider multiple sources of information, rather than to attempt to locate an important single factor in an hypothesized causal relation.

Different effects across outcomes. Although the utility of both biological risk and environmental factors for the prediction of outcome is established, the utility of either of these predictors may differ for different developmental outcomes. As the contribution of a predictor may vary for different outcomes, this allows us to consider possible explanations of development in various domains such as language, motor and attention skills. This conclusion has been presented in recent discussions of the prediction and explanation of developmental outcome (Horowitz, 1987; Scarr, 1991) and of issues more specific to the low birthweight research literature (Aylward et al., 1989; Hunt, 1986).

Horowitz (1987, 1989) has suggested a refinement of the transactional model proposed by Sameroff and Chandler (1975), applying it to different developmental domains, and considering that these domains may vary with respect to the contribution of either biological risk or environmental risk. More specifically, different developmental domains -- motor, language and attention -- may vary with respect to the influence of biological risk. Some domains may be more biologically determined and consist mainly of behaviours that require minimal environmental conditions in order to be acquired. Other domains may consist mainly of behaviours whose probability of acquisition is strongly influenced by environmental conditions. As a consequence, risks to development may differ for different domains of development. Biological risk represents an important factor for domains of development that consist primarily of behaviours requiring minimal environmental conditions for acquisition. Environmental risks represent an important factor for domains of development that consist primarily of behaviours whose acquisition is strongly influenced by environmental conditions. The optimal combination of biological and environmental conditions may be specific to a particular domain of development (Horowitz, 1987; 1989).

These conclusions have also been evident in various recent reviews of the low birthweight literature (Aylward, Gustafson, Verhulst, & Colliver, 1987; Aylward et al., 1989; Hunt, 1986; Murphy et al., 1982), although there have been a limited number of recent studies that have incorporated this approach to prediction and explanation in varied domains of development. The results of the current study, however, are consistent with the existing literature (Siegel, 1982) and support the suggestions and conclusions presented by Horowitz (1987). At each stage of the prediction analysis, the best prediction equation is different for each outcome measure and different for each aspect of attention. When infant factors (immaturity/illness, socioeconomic status, and the quality of the infant environment) are considered as potential predictors, socioeconomic status predicts language outcome, immaturity/illness predicts motor outcome, and the quality of the infant environment predicts all three aspects of attention. When infant developmental test scores are entered into the prediction analyses, the Bayley MDI and socioeconomic status predicts language outcome, and the Bayley MDI alone is selected as the predictor of motor outcome, inattention and impulsivity. When childhood environmental factors are entered into the prediction analyses, the Bayley MDI and maternal vocabulary predict language outcome; Bayley MDI and the quality of the child environment predict inattention and impulsivity; the MDI predicts motor outcome; and the quality of the child environment predicts hyperactivity.

These results, then, inform us that both biological and environmental factors contribute to developmental outcome across a variety of domains. However, motor, language, and attention domains of development may vary with respect to the influence of medical risk. Motor outcome may be more biologically determined and require minimal environmental conditions in order to be acquired. Medical risk, therefore, may represent an important factor for motor outcome. Language outcome may be determined by a combination of child characteristics (represented by the Bayley score) and both general stimulation (the quality of the environment) and specific stimulation (maternal vocabulary) provided by the caretaking environment. Attention outcome may also be determined by a combination of child characteristics and environmental factors. Inattention and impulsivity are both predicted by the Bayley MDI, possibly reflecting both immaturity/illness and either performance or problems of sustained attention during cognitive tasks. However, measures of inattention, impulsivity and hyperactivity also encompasses a number of behaviours whose probability of acquisition may be strongly influenced by environmental conditions. Environmental risks may represent an important factor for language and the various aspects of attention. Alternatively, the optimal combination of biological and environmental conditions may be specific to each domain of development.

Furthermore, the transactional model proposes both direct and indirect relations or paths between early medical risk and later outcomes, allowing one to emphasize the contribution, rather than the causal role, of medical risk to subsequent outcome. As the best prediction equation for each outcomes differs, it is possible to expect that the direct effects of each predictor will differ across outcomes, that indirect effects of each predictor will be evident despite its absence from a prediction equation, and that the total effects of each predictor (combined direct and indirect effects) will differ across outcomes. It could be expected that the total effects of immaturity/illness would be the greatest for motor outcome and the least for attention outcome. Alternatively, it could be expected that the total effects of infant environmental factors would be the greatest for attention outcome and the least for motor outcome.

# Chapter 3

## The explanation of childhood outcomes

Discussions that focus on the explanation of the relation between early medical risk and subsequent outcome have necessarily been limited by the correlational nature of the data concerning the consequences of low birthweight. Possible explanations have been implied in descriptive research, with a causal role for medical risk inferred on the basis of group differences, and in predictive research, with underlying developmental processes and factors contributing to stability of risk status inferred from patterns of relations among variables (Bornstein, 1989; Escalona, 1984). Research that has explicitly focused on explanations of the direct and indirect contribution of medical risk to specific aspects of childhood functioning has been limited. Existing explanatory research has focused on two themes -- the contrast between linear and transactional models of development, and the specificity of these models for different aspects of functioning.

### Multiple predictors of outcome: Transactional vs. linear models.

Linear models of the relation between early events and subsequent outcome assume an underlying continuity in either the child or the environment. Much of the descriptive research comparing outcomes between medical risk groups has implicitly endorsed such a linear model, although statistical and conceptual problems associated with such inferences have been raised (Escalona, 1984; Escobedo, 1988; Hunt, 1986; Kopp, 1983). The most important of these problems are that a relation (or absence of a relation) between low birthweight and childhood outcome does not permit causal inferences about the role of medical risk, and that group comparisons provide limited information concerning the influence of medical risk or environmental factors on variability within the low birthweight group.

In a discussion of the problems associated with explanations of the childhood consequences of low birthweight, Hoy et al. (1988) have distinguished between product-oriented research and process-oriented research. Product-oriented research has focussed on differences between low birthweight children and normal birthweight children. Process-oriented research has focussed on the effects of early abilities and experiences on later outcome and has been motivated by the discrepant findings of product-oriented research, as well as by the limited value of medical risk in accounting for variability within a sample. Hoy et al. (1988) advocated an emphasis on process-oriented research and the use of transactional models of development, suggesting that path analysis represents one means towards understanding the joint effects of medical risk and environmental factors.

Longitudinal predictive research has seriously challenged both the predictive and the explanatory power of linear models and has been suggestive of causal relations between medical risk, environmental factors, and childhood outcome, and of more complex models of development (Escalona, 1984; Schraeder, Rappaport, & Courtwright, 1987). Nonetheless, an interest in continuity between childhood outcome and single factors -- medical risk status, infant developmental status, socioeconomic status, or the quality of the environment -- has often been evident in multivariate research.

Continuity between early medical risk and childhood outcome has been one obvious and persistent focus of such research (Crisafi & Driscoll, 1989; Crisafi et al., 1989; Holmes et al., 1988; Michelsson, Ylinen, & Donner, 1981; Michelsson et al., 1984; Salamy et al., 1988; Silva et al., 1984; Zubrick, Macartney, & Stanley, 1988). For example, Crisafi and Driscoll (1989) attributed group differences in IQ in a low socioeconomic sample to birth weight alone, as low birthweight and comparison groups were equivalent on measures of socioeconomic status and the effect of birthweight less than 1000 g was evident within each socioeconomic group. Similarly, Holmes et al. (1988) explicitly stated their interest in the effects of medical risk, apart from the contaminating effects of other factors. To that purpose, children were designated as either high or low medical risk, but children from low socioeconomic status families were excluded from the sample. As high risk children tended to have lower scores on motor outcome measures at 5 years, Holmes et al. (1988) concluded that such problems persisted even in optimal environments.

Continuity between infant developmental status and childhood outcome has been another focus of this research (Bornstein, 1989; Hunt, 1986; Largo et al., 19 Klein et al., 1989; O'Connor et al., 1984; Siegel, 1981, 1984b; Tamis-LeMonda & Bornstein, 1989). This focus is due, in part, to practical concerns for the early identification of children at risk. Although there may be both statistical and theoretical explanations for relations between infant and childhood test scores (Kopp & McCall, 1982), an interest in continuity of underlying processes of development has been evident in the literature.

Bornstein (1989) has defined stability as consistency in the relative status of an individual within the group and suggested that such stability may be explained by test items that assess aspects of infant functioning that are related to later functioning (Bornstein, 1989). Hunt (1986) has noted that the assumption that specific aspects of childhood functioning have their origins in infancy has been accompanied by an expectation of continuity of either specific behaviours or underlying process. For example, McDonald et al. (1989) reported that early sensorimotor and representational abilities were correlated with later intelligence, and the correlations were greater for low birthweight children than for normal birthweight children within their sample. They attributed this in part to the greater variability of the low birthweight group, but also suggested these correlations provided evidence for continuity of process. Siegel (1981, 1984b) has reported consistent relations between infant and childhood test scores (Siegel, 1984b) and has concluded that there are continuities in cognitive functioning that are independent of specific behavioural changes.

However, the relation between infant and childhood measures might not be a direct one, and might be the consequence of an infant characteristic that shares variance with both infant and childhood measures (Bornstein, 1989). Such infant characteristics could include attentional factors. For example, Astbury et al. (1987) reported that inattentiveness, impulsivity and hyperactivity during testing at 2 years were more strongly related to 5-year cognitive outcome than was father's occupational status, and concluded that this relation signified an underlying continuity -- the presence or absence of a neurodevelopmental delay during infancy that was evident in various aspects of functioning 3 years later.

Continuity related to environmental factors has also been considered in the literature (Hunt, 1981; McDonald et al., 1989; Pfeiffer & Aylward, 1990; Siegel, 1981; Tamis-LeMonda & Bornstein, 1989), as environmental influences may either stabilize or destabilize individual differences and, therefore, represent a possible source of stability or instability in status between infancy and childhood. One approach has investigated the independent effects of environmental factors on childhood outcome. For example, Tamis-LeMonda and Bornstein (1989) applied path analytic techniques to determine if infant developmental status predicted childhood outcome beyond the contribution of the caregiving environment. Each factor made an independent contribution, suggesting stability in the child's functioning, and supporting the concept that infant characteristics and environmental factors make "joint contributions" to outcome. Another approach has investigated the compensatory effects of environmental factors (Hunt, 1981; Pfeiffer & Aylward, 1990; Siegel, 1981) For example, Pfeiffer and Aylward (1990) reported no differences among medical risk subgroups and a normal comparison group on childhood outcomes when socioeconomic status and maternal IQ were entered as covariates, and concluded that environmental factors may often compensate for early medical risk. Similarly, Siegel (1981) has suggested that environmental factors may compensate for early medical risk and may contribute to instability in status between infancy and childhood. However, Hunt (1981) has suggested that, for some children, there may limits to the effects of the environment, and that both child characteristics and experiential factors must be considered to account for stability in either risk status or functioning.

Identifying multiple effects. Despite this interest in continuity related to individual factors, most recent reports have deliberately acknowledged multiple influences on development. Efforts to specify either the relative contribution of child characteristics or the mechanisms underlying relations among variables have been infrequent, but have included both categorical (Cohen et al., 1982; Cohen, Parmalee, Sigman, & Beckwith, 1988; Crisafi et al, 1987; Hunt, Cooper, & Tooley, 1988) and correlational (Drillien et al., 1980; Schraeder et al., 1987; Siegel, 1982a) analyses.

Cohen et al. (1982, 1988) reported that, although a delayed 5-year-old group had higher scores on medical risk measures than did a normal group, the quality of the environment distinguished high medical risk infants with poor childhood outcomes from high medical risk infants with good childhood outcomes. Therefore, the contribution of medical risk could not be ignored, but neither could the impact of the caregiving environment. Using another type of categorical analysis, Hunt et al. (1988) dichotomized ratings of parent education and neonatal illness and reported that changes in the frequency and severity of developmental problems during childhood were related to these two factors. Level of illness appeared to influence the likelihood of a normal outcome. A shift toward more severe problems was noted among the low education group; in combination with high illness, there was a shift towards even greater numbers of more severe problems. They concluded that these factors do not exert independent effects and that medically high-risk children were more vulnerable to less-than-optimal environmental effects. In contrast, Crisafi et al. (1987) concluded that environmental factors appeared to be more important than medical risk for low socioeconomic children, as illness demonstrated a significant effect only within the high socioeconomic subgroup within the sample.

Siegel (1982a), who explicitly endorsed a transactional model of development, used regression analyses to identify a combination of medical risk and demographic variables that predicted outcome, and also reported that infant test scores improved the accuracy of prediction in discriminant function analyses. As all the variance was not accounted for by these measures, Siegel considered the role of the quality of the infant environment and determined the relative contribution of each variable using partial correlation techniques. When SES was partialled out, there were consistent correlations between 12-month HOME and 3-year outcome and, when 12-month Bayley score were partialled out, there were consistent correlations between the HOME and 3-year outcome, suggesting an independent influence of the infant environment. In another correlation-based approach, Schraeder et al. (1987) reported that a combination of medical risk measures and the HOME score accounted for 27% of the variance in 3 year outcome in a multiple regression analysis. With respect to the causal role of the environment, Schraeder et al. (1987) conducted a cross-lag panel analysis. As the correlation between 6-month HOME and 36-month developmental score was significantly larger than the correlation between 6-month developmental score and 36-month HOME score, this suggested a causal influence of the early home environment.

Drillien et al. (1980) reported that medical risk, socioeconomic status, and evidence of minor neurological abnormality during infancy each demonstrated an independent influence on subsequent outcome in multiple regression analyses. However, Crisafi et al. (1987) reported that the inclusion of prior test scores in regression analyses rendered socioeconomic status a nonsignificant predictor, although illness continued to account for a small amount of variance, and concluded that the effects of these factors were expressed indirectly via prior test scores. Similarly, Field et al. (1983) suggested that path analysis may reveal the specific paths by which prior test scores, the quality of early social environment, and maternal education, predictors of cognitive outcome, contribute to later performance.

The research, then, has been characterized by different approaches to identifying the multiple influences on developmental outcome. Correlational and multiple regression analyses represent an approach that can identify sources of variability in childhood outcome within a low birthweight sample and determine the predictive utility of certain variables, after the effect of other variables are considered. Partial correlation techniques may be useful, but may not incorporate a conceptual model of all of the interrelations among variables. Furthermore, although such techniques can provide information concerning the unique contribution of a particular variable, they may not permit the researcher to simultaneously determine the unique contributions of a number of factors. However, multiple regression analyses do not easily permit the discussion of the relative effects of the variables not entered into the equation (Pedhazur, 1982).

Path analytic techniques represent an exploratory but potentially useful approach to identifying the relative contributions of various factors to the development of low birthweight children, as they can be used to identify direct and indirect effects of different variables in models of development (Schraeder et al., 1987). Despite suggestions about the utility of these techniques (Field et al., 1983; Schraeder et al., 1987), their application to models of development has been rare in the low birthweight literature. Hack and Breslau's report (1986) represents one of a limited number that have used path analysis, although their primary purpose was to control for the contribution of medical risk and environmental factors so that the contribution of brain growth (as indexed by head circumference) during infancy could be evaluated. Both head circumference and demographic factors had direct effects on 3-year-old IQ; neurological impairment had both direct and indirect effects; and medical risk had an indirect effect via head circumference. Hack and Breslau concluded that 3-year IQ was directly affected by biological factors (accounting for 30% of explained variance), social factors (accounting for 63% of explained variance) and joint effects of these (7%); that the effect of medical risk was expressed indirectly via head circumference; and that social factors exerted an effect that was independent of biological risks.

Perhaps the most important advantage of path analysis is that this technique is especially appropriate for evaluating transactional models, the type of model that may be the most appropriate for explaining developmental outcomes among low birthweight infants. Furthermore, despite the correlational nature of this research, possible causal relations among the variables of interest can be suggested and the likelihood of these relations can be evaluated.

Different effects across outcomes: Different explanatory models.

As patterns of prediction differ for different aspects of childhood functioning, the need to discuss explanations of these predictive relations with more specificity has also become evident (Caputo et al., 1981; Mazer et al., 1988; Pfeiffer & Aylward, 1990; Siegel, 1982b). For example, Siegel (1982b) explicitly attempted to determine the relative importance of medical risk and environmental factors for specific aspects of childhood functioning, based on the order of entry of variables into the regression equation. The best prediction for all aspects of functioning was obtained via a combination of variables, but there was a differential impact of medical risk on different outcomes. Medical risk measures were more likely to be significant predictors of motor outcome, environmental predictors were more important than medical risk for language, and infant tests significantly increased the variance accounted for in language. These analyses suggested a greater effect of environmental factors on childhood language. Similarly, Mazer et al. (1988) observed that medical risk may differentially influence different aspects of functioning among all but the most immature children. Analyses indicated that there were significant differences among skill areas only for children who had weighed more than 750 g. These results suggested that, among the smallest children, all skill areas were influenced by medical risk and that, although development was negatively influenced by low birthweight, the effect of low birthweight varied according to the skills assessed. Motor skills might be more negatively influenced by medical risk, and the early environment may have a relatively greater influence on language skills. Finally, Pfeiffer and Aylward (1990) reported multiple regression analyses indicating that language was relatively more sensitive to environmental factors and concluded that medical risk and environmental factors appeared to differentially influence various aspects of functioning.

The research, then, has suggested that models of developmental outcome may be specific to certain aspects of functioning. Among low birthweight children, the relative contributions of medical risk and environmental factors may vary for language, motor and attention skills. Existing research has adopted a variety of approaches to determining the relative contributions of different variables to language, motor and attention outcome and has presented a variety of possible interpretations for observed relations among variables.

Language outcome. The existing literature has suggested that there are multiple influences on language outcome among low birthweight children, including a contribution of biological processes that may be expressed indirectly via infant developmental status or measures of the infant environment. Furthermore, there be may a contribution of infant developmental status due to a continuity in underlying processes of language development. Finally, there may be a contribution of concurrent measures of the quality of the environment, as a reflection of either biological factors and experiential factors, including both general stimulation and specific stimulation of language.

Interpretations of the relative importance of medical risk and environmental factors to language outcome have varied (Astbury et al., 1990; Crisafi et al., 1987; Largo, 1987; Largo et al., 1986, 1990; Rocissano & Yatchmink, 1983; Siegel, 1979, 1981; Vohr et al., 1989). Existing evidence has suggested that medical risk may make an important contribution to language outcome, but that both medical risk and aspects of the infant environment may contribute to childhood language outcome. For example, Largo et al. (1986) noted that environmental influences have been thought to be more important than biological influences, but reported that 3-year language was more strongly related to medical risk than to socioeconomic status. At 5 years of age, medical risk was still an important influence, but socioeconomic status had become a significant factor, suggesting that environmental factors became more important with increasing age. Largo et al. (1989) also considered the relative influences of various medical risk factors and concluded that immaturity was the most useful medical risk measure for predicting language outcome and that socioeconomic status may reflect both genetic and experiential factors. However, as low functioning children were represented in all gestational age groups, they concluded that socioeconomic status also significantly affected language.

The explanatory power of measures of infant developmental status has also been considered. Some interpretations have suggested that such measures may indirectly reflect the impact of medical risk and infant environmental factors. For example, Crisafi et al. (1987) reported that, when prior developmental test scores were included in regression analyses, socioeconomic status was no longer a significant predictor of language, but illness continued to account for a small amount of variance. Therefore, they concluded that the effects of socioeconomic status and illness were expressed indirectly via prior test scores.

Other interpretations of the relation between measures of infant development and child language have suggested a continuity of underlying biological or developmental processes. For example, Astbury et al. (1990) reported that, when socioeconomic status and infant behaviour during developmental testing (inattentiveness, impulsivity and hyperactivity) were statistically controlled, 5-year language outcome was more highly correlated with PDI than with MDI. Therefore, the relations between early developmental status and later language persisted, suggesting a continuity in processes tapped by both developmental measures.

Siegel (1979, 1981) has endorsed a transactional model by discussing continuity in processes related to language, but also considering the influences of quality of the environment. She reported that the Bayley PDI was more highly correlated with toddler language than the MDI and that HOME scores were also correlated with language (Siegel, 1981). Bayley scores were relatively better predictors than was the HOME for early language, whereas the HOME was a better predictor of childhood language (Siegel, 1979). Siegel (1979, 1981) interpreted these findings as suggestive of continuity in underlying processes of language development and speculated that the relation with infant motor skills may be due to a maturational component in language development. Furthermore, certain aspects of early cognitive development assessed by the 12-month Bayley MDI, such as object permanence and gestural imitation, might be related to the acquisition of language. However, she acknowledged that infant developmental status alone might not be the best predictor of subsequent outcome, as the environment might either compensate for early delays or increase the chance of childhood language delay (Siegel, 1979).

The explanatory power of measures of environmental factors has also been considered. However, the difficulty of interpreting relations between environmental measures and language has been noted, as there is a possible confound between genetic and environmental influences (Luster & Dubow, 1991). For example, discussing normative data, Schiamberg and Lee (1991) reported that the HOME inventory, maternal intelligence, and family income predicted child language in multiple regression analyses. As the magnitude of standardized betas for the HOME and maternal IQ were comparable, they were assumed to be equally important. Therefore, the quality of the home environment was not simply a reflection of maternal intelligence, but made an independent contribution. Furthermore, Schiamberg and Lee speculated that many environmental correlates not identified as predictors exerted an indirect influence on language. Similarly, Luster and Dubow (1991) used path analysis to identify the most important aspects of the environment for language outcome. Hierarchical multiple regression analyses indicated that there was a significant effect of both the quality of the home environment and maternal intelligence on children's vocabulary when the effect of the other was statistically controlled, but that the effect of the home environment appeared to be relatively stronger for preschool children. These predictors, as well as maternal education and socioeconomic status, were incorporated into a model of language and path analyses were conducted. Maternal intelligence and the HOME inventory were significant predictors of language outcome, and maternal intelligence exerted both a direct and an indirect effect. Therefore, despite the fact that measures of the quality of the environment may reflect the influence of both biological and experiential factors, the literature has suggested that both status and qualitative environmental variables may make a contribution to language.

Rocissano and Yatchmink (1983) considered processes underlying the relation between such qualitative variables and language, speculating that parent modelling, expansion of language, and direction of child attention to the environment might be relevant to language learning. They reported that mothers of children with poorer language skills tended to be less sensitive in interactions with their children (either highly directing or highly uninvolved) and, therefore, less effective in directing and maintaining the child's attention. Although they described their sample as healthy preterm children, they did not report any information concerning the role of medical risk for language outcome. Rather, they characterized the low birthweight child as possessing limited resources to expend for psychological functioning. Therefore, variations in the quality of the environment become an important source of variance in language outcome. Furthermore, they suggested that the influence of the quality of the infant environment on childhood functioning may be indirect, as it influences infant development, that in turn influences the quality of subsequent social interactions.

Motor outcome. The existing literature has suggested an important contribution of medical risk to subsequent motor outcome and interpreted this contribution as a reflection of important biological or maturational influences on motor development. However, this effect may be indirect rather than direct. The explanatory power of environmental factors for motor development has not been clear, as socioeconomic status may be related to motor outcome as a result of variance shared with genetic or biological factors or with qualitative measures of the environment. Finally, the literature has reported considerable stability in motor functioning and implied, indirectly, that concurrent measures of the quality of the child environment may not make an important contribution to individual differences in motor development.

Interpretations of the relative effects of medical risk and environmental factors on motor outcome have been varied (Aylward et al., 1987; Crowe et al., 1988; Klein et al., 1985; Marlow et al., 1989; Sobotkova, Mandys, Tautermannova, & Dittrichova, 1989; Wallace et al., 1982), but have strongly suggested an important contribution of early medical risk. For example, Crowe et al. (1988) considered continuity between medical risk and childhood motor skills by way of descriptive analyses, reporting that extremely low birthweight (<750 g) children and children who had experienced intraventricular hemorrhage had significantly lower scores on measures of fine and gross motor skills. This suggested continuity between early biological risk and central nervous system insult and later motor development. Similarly, Marlow et al. (1989) compared extremely low birthweight children to a normal birthweight group equated on socioeconomic factors and, therefore, dismissed the influence of environmental factors on the delayed motor skills of the extremely low birthweight children.

Findings of relatively greater stability in motor functioning have also been used to infer a contribution of early medical risk to later motor development, and a relatively smaller contribution of environmental factors. For example, Aylward et al. (1987) reported greater stability of motor status than of cognitive status between 9 and 36 months of age among children classified as normal during infancy, and that demographic factors influenced cognitive outcome only. Wallace et al. (1982) suggested, on the basis of multiple regression and canonical correlation analyses, that tasks involving motor abilities were less readily influenced by the social environment than were language processes.

Nonetheless, there has been some inconsistency concerning the contribution of environmental factors to motor outcome among low birthweight children. For example, Sobotkova et al. (1989) reported considerable stability in childhood visual motor problems, but noted that both neurological abnormalities and lower levels of parent education were risk factors for motor outcome, although they did not speculate on the reason for this relation. Based on both group comparisons and correlational analyses, Klein et al. (1985) suggested that the determinants of differences between low birthweight and normal birthweight children on visual-motor skills might be multiple and may include minor neurological problems and environmental, educational, and psychological correlates of social class. Furthermore, they suggested that, although minor central nervous system insult might be the basis of childhood motor deficits, these deficits might be more likely to occur in combination with poor environmental conditions. However, Aylward et al. (1987) reported, based on categorical and nonparametric analyses, that motor functioning was more stable than and not as influenced by demographic factors as cognitive functioning between birth and 3 years. They speculated that this greater stability reflected the relatively weaker influence of environmental factors and concluded that instability was attributable to compensatory abilities of the central nervous system, rather than to environmental factors.

Attention outcome. The low birthweight literature has infrequently focused on the explanation of attention outcome, and existing research has been both suggestive and inconsistent. Interpretations of the relative importance of medical risk, environmental factors and infant developmental status have been varied.

Rapoport and Ferguson (1981) summarized the classic risk research and concluded that there were very weak relations between measures of medical risk and attention deficits, that environmental factors were relatively more important predictors, and that multivariate analyses were the most informative. Specifically, relations between medical risk and attention problems were more likely among children in economically disadvantaged or non-supportive caretaking environments. Therefore, rather than concluding that biologically vulnerable children may be more susceptible to the impact of environmental factors, they concluded that there might be some children for whom environmental factors would not compensate for early medical risk. Environmental risk might compound medical risk, but the strongest evidence for biological influences might be appropriate for only a small subgroup of hyperactive children.

Nonetheless, there has been considerable interest in the explanatory power of medical risk for attention problems among low birthweight children. For example, Calame, Fawer, Claeys, Arrazola, Ducret, and Jaunin (1986) focused on child characteristics and explicitly minimized the influence of environmental factors, maintaining that it was impossible to understand the consequences of medical risk unless environmental factors were controlled. Similarly, Breslau, Klein, and Allen (1988) discussed the absence of models of specific effects of medical risk on subsequent outcome, noted the inconsistent evidence concerning the relation between medical risk and subsequent attention deficit, and attributed this inconsistency to methodological factors. Therefore, their sample was homogeneous with respect to demographic factors. Multiple regression analyses indicated that medical risk exerted an independent effect on attention problems and they concluded that, due to the control of demographic factors, organic factors accounted for the group differences they reported.

Szatmari et al. (1990) focused on the relation between low birthweight and attention problems among a sample of extremely low birthweight children and explicitly challenged the conclusion that medical risk makes a minimal contribution to childhood attention problems. In particular, they characterized environmental factors as confounds, to be controlled either through matching or statistical control. Attention deficits in their sample and among a comparison group were identified. Nonparametric analyses indicated that there was no effect of an interaction with environmental factors on the association between low birthweight and attention problems. Accordingly, they argued against a multivariate model of attention problems (Szatmari et al., 1990). Stepwise regression analyses that considered birthweight, demographic risk factors, family risk factors and developmental problems indicated that only developmental problems improved the fit of the model. When this effect was controlled, the association between birthweight and attention problems became nonsignificant. Therefore, they concluded that the relation between low birthweight and attention problems could not be explained by the confounding influence of environmental factors, that medical risk contributed to developmental problems, and that attention deficits and developmental problems arise from a common source, impairment of the central nervous system.

However, not all research reports have supported the explanatory power of medical risk for attention outcome. For example, Astbury, Orgill, Bajuk, and Yu (1985) categorized children as hyperactive or normal on the basis of behaviour during developmental testing in infancy. As hyperactive and normal children did not differ on measures of immaturity, they concluded that attention problems were associated with lower scores on developmental measures, but that it was impossible to determine whether these problems were causally related to low birthweight alone or to low birthweight in combination with other variables.

There has also been inconsistency concerning the antecedents of childhood attention problems during infancy, as reflected by measures of infant developmental status (Astbury et al., 1987, 1990; Dunn et al., 1980; Palfrey, Levine, Walker, & Sullivan, 1985; Sigman et al., 1987). Astbury et al. (1987) reported considerable stability in attention problems between 2 years and 5 years of age and interpreted this relation as indicative of an underlying continuity in the child (Astbury et al., 1990). Similarly, Sigman et al. (1987) reported significant correlations between a measure of sustained attention at 2 years and maternal ratings of attention span at 5 years and concluded that the underlying continuity of sustained attention skills was independent of the contribution made by cognitive abilities. Vohr et al. (1989) investigated the contribution of 8-month neurological status to attention problems during toddlerhood, that were assessed by way of a rating of behaviour during testing. When socioeconomic status was statistically controlled, there were no differences between low birthweight children and a comparison group. However, there appeared to be a significantly larger percentage of low birthweight children with attention problems. They concluded that, although obvious signs of central nervous system insult were no longer evident, insults that affected functioning may have still persisted. However, in a prospective longitudinal study, Palfrey et al. (1985) reported that, on the basis of behaviour during developmental testing, only 3% of children during infancy met criteria for possible concerns and that the frequency of diagnoses of attention problems increased between infancy and early childhood. They speculated that either most children with attention deficits did not demonstrate these problems during infancy, or that the observable symptoms were different during infancy. However, when the stability of attention problems was examined, children in a persistent problem group had mothers with a lower level of education, were more likely to come from single parent families, and had more mental and motor delays. These data suggested that, for those whose attention problems were evident early and persisted, there were relations with infant developmental status, quality of the environment, and childhood outcome. Children whose attention problems abated between infancy and early childhood were conceptualized as a group for whom child characteristics (a higher level of cognitive skills) and environmental factors (higher levels of parent education and lower levels of family stresses) had functioned as protection against persistent problems.

Normative data concerning the relative contributions of various environmental factors to early childhood attention problems were reported by Schiamberg and Lee (1991) in a discussion of data obtained in a longitudinal study of a large heterogeneous sample. Multiple regression analyses indicated that, with respect to attention/behaviour problems, the HOME inventory, rather than maternal intelligence, family income, and marital status, was identified as a predictor. Tobey and Schraeder (1990) were particularly interested in the contribution of the caregiving environment to childhood attention problems. More specifically, they suggested that there may be an "indirect" pathway between economic disadvantage (a marker for family stress) and childhood outcome via the caregiving environment, and considered the notion that low birthweight children may be relatively more vulnerable to the effects of the caregiving environment. Correlational analyses indicated that higher levels of economic stress and lower HOME scores were associated with child hyperactivity. When the HOME score was partialled out, the correlation between stress and child adjustment was reduced and nonsignificant. They noted that there was no information concerning the contribution of child characteristics to these problems, but speculated that there might be a possible interaction between child variables and parent stress that contributed to childhood attention problems.

The existing literature has presented inconsistent conclusions concerning the contribution of medical risk to childhood attention outcome and the explanatory power of environmental factors for attention development has also been debated. Status measures of the environment may influence attention development as a result either of their relation with genetic or biological factors or their relation with more qualitative measures of the environment. Similarly, there has been inconsistency in the literature concerning the stability of attention problems between infancy and childhood. Existing evidence has suggested that the best evidence for stability has been obtained from observations of child behaviour during developmental testing, suggesting that infant developmental status, as an indirect reflection of continuity in attentional abilities, may make an important contribution to childhood attention outcome. Furthermore, concurrent measures of the quality of the child environment may make an important contribution to individual differences in attention outcome and may influence the likelihood of attention problems among children at medical risk.

Implications for the current study.

The findings of research that has considered the explanation of language, motor and attention outcomes among low birthweight children has several implications for the current study. It was expected that both medical risk and environmental factors would contribute to all aspects of childhood functioning. Second, the relative contribution of medical risk and environmental factors would differ for different aspects of childhood functioning.

Hypotheses

The multiple influences on language outcome will be expected to include a contribution of medical risk, that may be expressed indirectly via infant developmental status or either status or qualitative measures of the infant environment. Furthermore, there be may a relation between infant developmental status and child language outcome. Finally, concurrent measures of the quality of the environment during childhood will also make an important contribution to language. These may include both general stimulation as well as specific stimulation of language.

Medical risk is expected to make an important contribution to subsequent motor outcome. However, this effect may be indirect rather than direct. The explanatory power of environmental factors for motor development has not been clear, as status measures of the environment may influence motor development as a result of shared variance with genetic or biological factors or as a result of their relation with more qualitative measures of the environment. Finally, considerable stability in motor functioning has been reported. Therefore, concurrent measures of the quality of the child environment may not make an important contribution to individual differences in motor outcome.

There have been inconsistent conclusions concerning the contribution of medical risk to childhood attention outcome. Therefore, its effect may be indirect rather than direct. The explanatory power of environmental factors for attention development has also been debated. Similarly, there has been inconsistency in the literature concerning the stability of attention problems between infancy and childhood. Existing evidence has suggested that the best evidence for stability has been obtained from observations of child behaviour during developmental testing. Therefore, infant developmental status will make an important contribution to childhood attention outcome. Existing evidence has also suggested that concurrent measures of the quality of the child environment will make an important contribution to individual differences in attention outcome.

## Method

Overview. On the basis of the previous research and the results of the multiple regression analyses, models of the development of language, motor and attention outcomes were formulated and evaluated by way of path analysis. These analyses were conducted with the data obtained from the children participating in the current study and the models were formulated using the same aggregate measures that had been developed for the purpose of prediction analyses.

The primary objective of the path analyses was to evaluate models of language, motor and attention outcomes. Several additional purposes were addressed. First, these analyses determined if the data supported multiple influences on each of these aspects of childhood functioning and identified contributing influences that may not have been selected as predictors in multiple regression analyses. Second, these analyses demonstrated whether there were different contributions of medical risk and environmental factors across different childhood outcomes. The analyses identified the direct and indirect contributions of medical risk, the quality of the infant environment, infant socioeconomic status, infant developmental status, the quality of the child environment and maternal vocabulary to language, motor and attention skills.

A linear structural relations (LISREL) analysis, a more elaborate form of path analysis, was conducted to determine the contributions of immaturity/illness, infant environmental factors, infant developmental status, and childhood environmental factors to these specific aspects of functioning. LISREL was chosen because this approach to testing the hypothesized models possesses several advantages over a simple path analysis. One major advantage of LISREL is that the analyses are conducted in a single stage, and several indices for confirmation of the model, as well as indices of total, direct, and indirect effects of each variable on the outcome, are generated (Biddle & Marlin, 1987). Path coefficients, that identify significant pathways among components of the model, are generated. Each path coefficent represents the direct effect of an explanatory variable on a variable hypothesized to be dependent upon it (Pedhazur, 1982). A path coefficient is equivalent to a zero-order correlation when a variable is hypothesized to be dependent on either a single explanatory variable or multiple independent explanatory variables (Pedhazur, 1982), and equivalent to a standardized regression coefficient when the multiple explanatory variables are not independent (Pedhazur, 1982). In addition to these path coefficients, LISREL generates several statistics that allow for the evaluation of the fit of the model to the pattern of intercorrelations among the components of the model. These statistics include a measure of the goodness-of-fit of the model, a chi-square goodness-of-fit index, and an $R^2$ for each equation in the model. The value of the goodness-of-fit index for the entire model is based on a contrast between the predicted and observed variances and covariances of variables in the model and ranges from zero to one, with one indicating a perfect fit between the model and the data (Anderson, 1987). With respect to the chi-square goodness-of-fit index, a small, nonsignificant chi-square statistic is interpreted as an indication that the model is consistent with the observed data (Pedhazur, 1982). Indices of the direct and indirect effects of an hypothesized explanatory variable on the outcome variable represent a decomposition of the correlation between these two variables (Pedhazur, 1982). All parameters are estimated by that maximum-likelihood method (Joreskog & Sorbom, 1989), that yields estimators of the paramaters most likely to have generated the observed data (Pedhazur, 1982). In each analysis, a matrix of the correlations among components of the model was the basis of the LISREL analysis.

# Results

## Language outcome

The hypothesized model of language outcome and the zero order correlations between the components of the model are presented in Figure 2. The predictors were those measures used in the multiple regression analyses: the aggregate measures of immaturity/illness, infant socioeconomic status, and the quality of the infant environment; the Bayley MDI score; the measure of the quality of the home environment; and the measure of maternal vocabulary. The outcome measure was the aggregate measure of child language skills.

It was hypothesized that immaturity/illness would make an indirect contribution, via infant developmental status (Bayley MDI), to language outcome; that infant socioeconomic status would make an indirect contribution via the quality of the infant and child environment, and via maternal vocabulary; that the quality of the infant environment would make an indirect contribution, via infant developmental status (Bayley MDI) and the quality of the child environment; that infant developmental status (Bayley MDI) would make a direct contribution; that maternal vocabulary would make a direct contribution and an indirect contribution, via the quality of the child environment; and that the quality of the child environment would make a direct contribution to child language.

The full explanatory model and the path coefficients are presented in Figure 3. The goodness-of-fit measure for

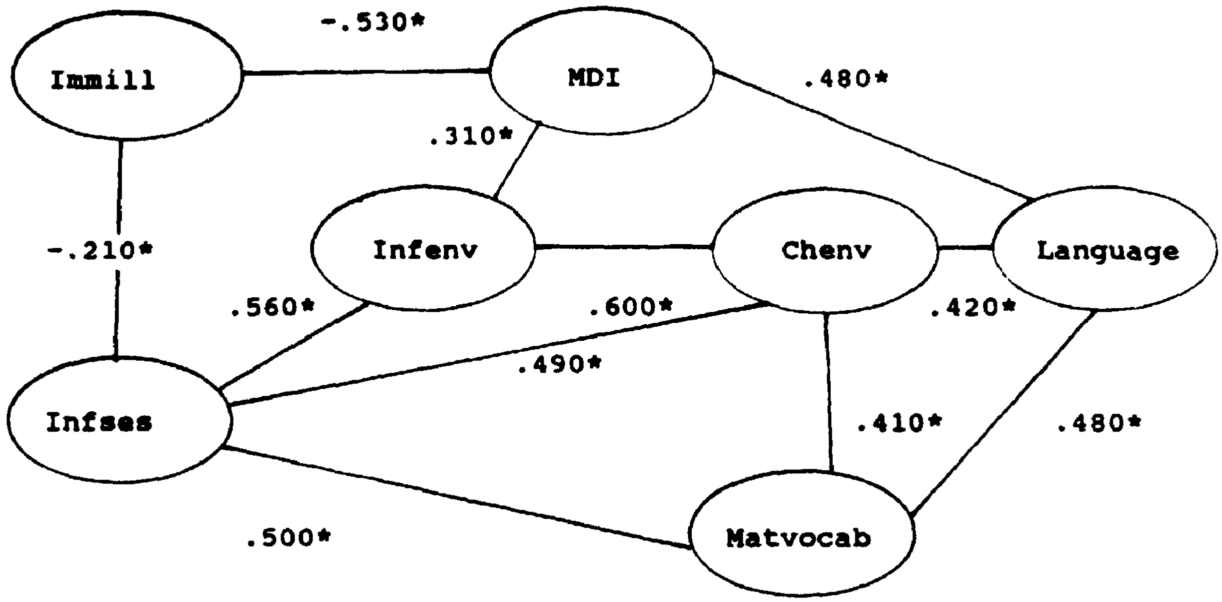


Figure 2. Explanatory model of language outcome and zero-order correlations coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

Coefficients with an asterisk are significant at $p < .05$.

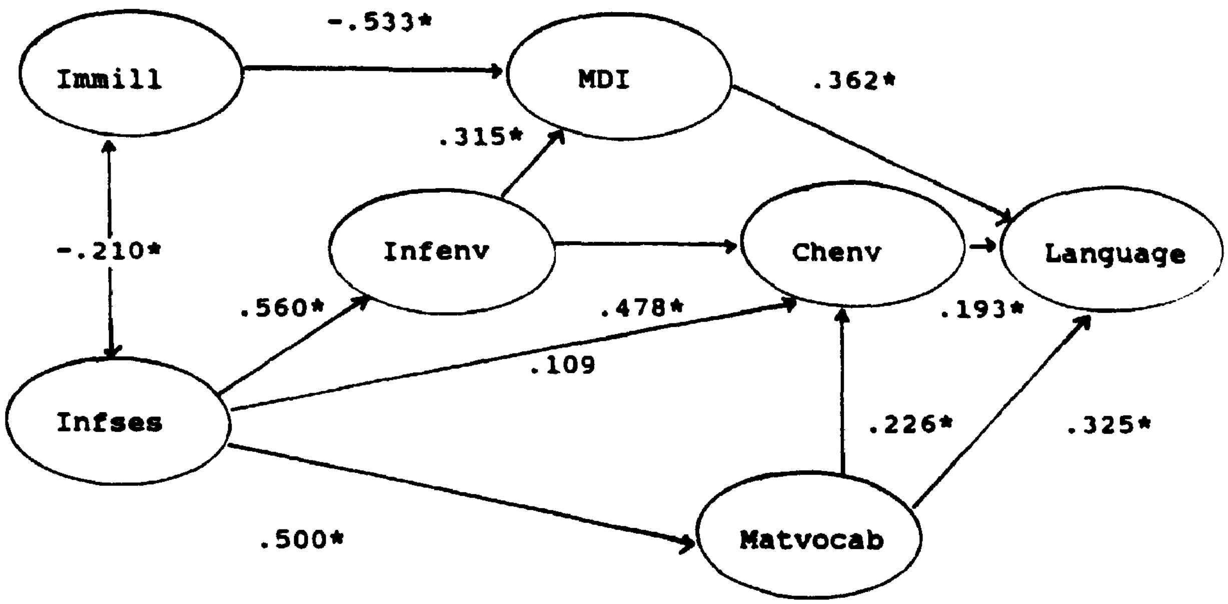


Figure 3. Explanatory model of language outcome and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

Coefficients with an asterisk are significant at $p$ <.05.

the model was acceptable (.930, adjusted to .850). However, the chi-square goodness-of-fit measure was significant, chi-square = 25.37 (*df* = 13, *p* = .021), indicating that the model was not confirmed as a whole, and suggesting that one part of the causal model did not truly fit the data set (Biddle & Marlin, 1987). Nine of the ten predicted paths produced significant path coefficients. Although the goodness of fit measures indicated an acceptable fit between the model and the data, the model as a whole was not supported because the chi-square statistic was significant and one of the paths was nonsignificant. Therefore, the nonsignificant path between infant socioeconomic status and the quality of the child environment was fixed at zero and the model was retested.

The revised explanatory model and the path coefficients are presented in Figure 4. The goodness-of-fit measure for the model was acceptable (.930, adjusted to .861). Once again, however, the chi-square goodness-of-fit measure was significant, chi-square = 26.36, (*df* = 14, *p* = .023), indicating that the model was not confirmed as a whole. Subtracting the chi-square and degrees of freedoom of the full model from those of the reduced model, following the procedure for nested models, yielded a nonsignificant chi-square of .99 (*df* = 1) (Hayduk, 1987). Therefore, the full model did not represent a significantly better fit to the data than the reduced model, that showed the measure of

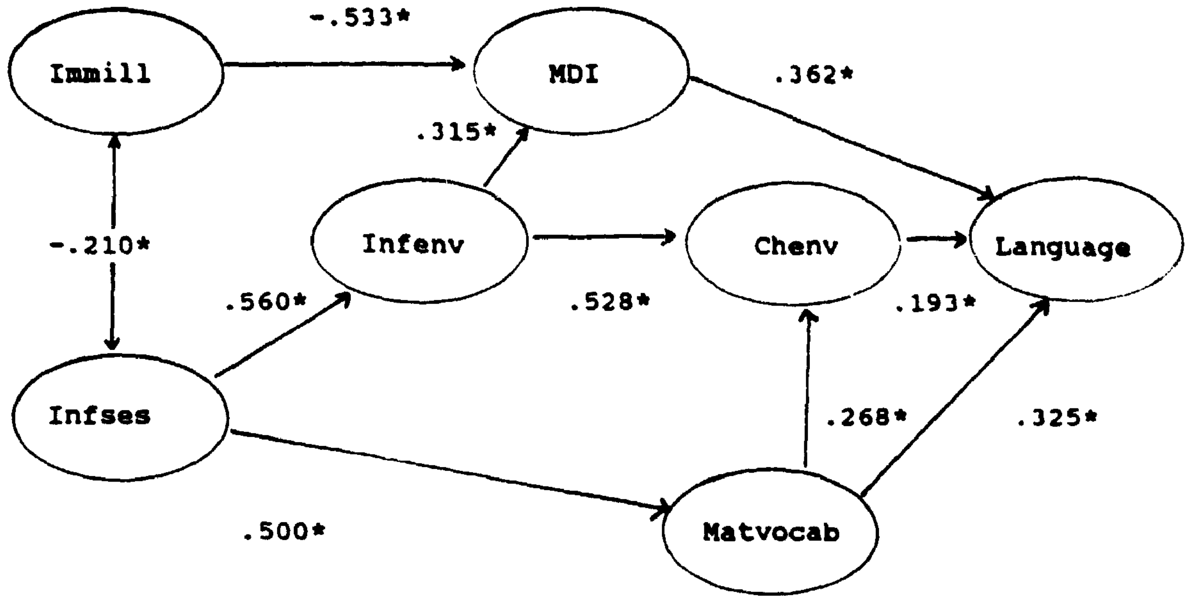


Figure 4. Revised explanatory model of language outcome and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

Coefficients with an asterisk are significant at $p < .05$.

infant socioeconomic status to have an effect on language outcome through indirect paths.

At the level of individual equations, the results are as follows: for infant developmental status (Bayley MDI), $R^2 = .382$; for quality of the infant environment, $R^2 = .314$; for quality of the child environment, $R^2 = .428$; for maternal vocabulary, $R^2 = .250$; for language outcome, $R^2 = .388$. At the level of specific predictive paths between variables, all nine of the hypothesized path coefficients were significant at the $p < .05$ value. Immaturity/illness had a negative influence on infant developmental status ($B = -.533$, $t = -6.24$) that, in turn, had a positive influence on language outcome ($B = .362$, $t = 4.27$). Infant socioeconomic status had a positive influence on the quality of the infant environment ($B = .560$, $t = 6.23$) that in turn, had a positive influence on infant developmental status ($B = .315$, $t = 3.69$), and the quality of the child environment ($B = .528$, $t = 6.17$). Infant socioeconomic status had a positive influence on maternal vocabulary ($B = .500$, $t = 5.32$). Maternal vocabulary had a positive influence on the quality of the child environment ($B = .268$, $t = 3.12$) and on language outcome ($B = .325$, $t = 3.55$). The quality of the child environment had a positive influence on child language ($B = .193$. $t = 2.08$).

The significance of the chi-square statistic in the revised model suggested that the proposed model did not truly fit the data set. However, this measure of the degree of fit between the model and the data set is independent of other criteria for the confirmation of the model (Biddle & Marlin, 1987) -- the proportion of variance explained, the significance of the path coefficients and the goodness of fit index. The analyses of the model of language development indicated that 38% of the variance in childhood language outcome was explained, demonstrated significant pathways among components of the model, and resulted in an acceptable overall goodness of fit.

The model supported direct effects of infant developmental status, the quality of the child environment, and maternal vocabulary on child language outcome. The model supported indirect effects of immaturity/illness, infant socioeconomic status and the quality of the infant environment on child language outcome. The direct effects, indirect effects and total effects of each predictor on language outcome are presented in Table 26. The path coefficients for the direct pathway between each predictor and the language outcome measure represent the direct effect of that predictor. The sum of the product of path coefficients for indirect pathways between each predictor and the outcome measure represents the indirect effect of that predictor. The total effects is the sum of direct and indirect effects of each predictor.

As indicated in Table 26, immaturity/illness, infant soceioeconomic status and the quality of the infant environment had indirect effects on language outcome.

Table 26

Indirect, direct and total effect coefficients for language outcome.

| | Effect coefficient | | |
|---|---|---|---|
| Variable | Indirect | Direct | Total |
| Immill | -.193 | --- | -.193 |
| Infses | .309 | --- | .309 |
| Infenv | .216 | --- | .216 |
| MDI | --- | .362 | .362 |
| Chenv | --- | .193 | .193 |
| Matvocab | .052 | .325 | .377 |

Note. IMMILL=Aggregate measure of immaturity/illness; INFSES=Aggregate measure of infant socioeconomic status; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version; MATVOCAB=Maternal Peabody Picture Vocabulary Test-Revised standard score.

Immaturity/illness had an indirect effect through infant mental development (-.193). Infant socioeconomic status had an indirect effect (.309) through four pathways. The quality of the infant environment had an indirect effect (.216) through infant mental development and the quality of the child environment. Infant mental development had a direct effect (.362). The quality of the child environment had a direct effect (.193), whereas maternal vocabulary had both direct (.325) and indirect (.052) effects.

Motor outcome

The hypothesized model of motor development and the zero order correlations between the components of the model are presented in Figure 5. The predictors were those measures used in the multiple regression analyses: the aggregate measures of immaturity/illness and the quality of the infant environment; and the Bayley PDI score. The outcome measure was the aggregate measure of child motor skills.

It was hypothesized that immaturity/illness would make a direct contribution and an indirect contribution, via infant developmental status (Bayley PDI), to motor outcome; that the quality of the infant environment would make an indirect contribution, via infant developmental status (Bayley PDI); and that infant developmental status (Bayley PDI) would make a direct contribution to child motor development. It was also predicted that the contribution of

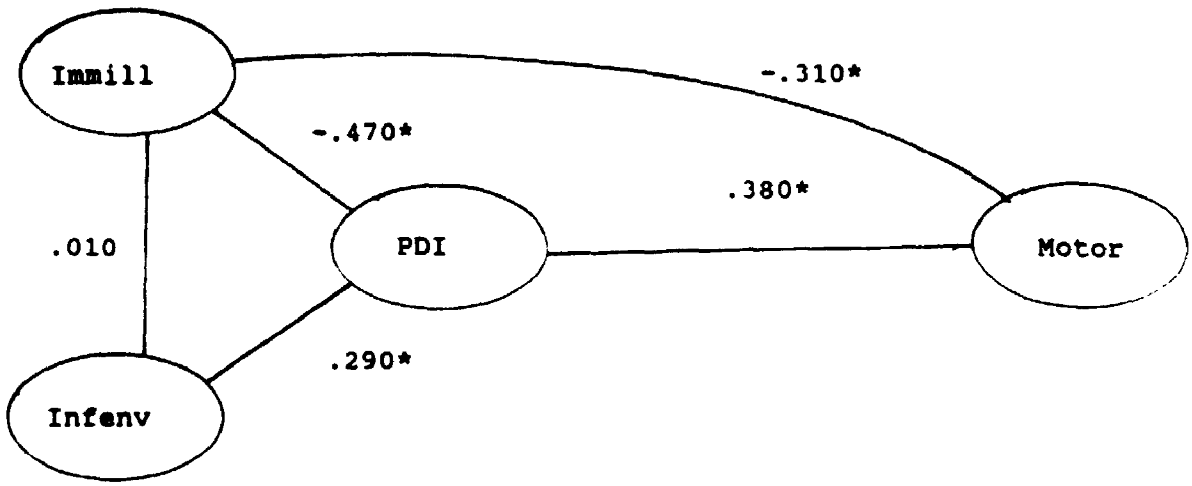


Figure 5. Explanatory model of motor outcome and zero-order correlations coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index.

Coefficients with an asterisk are significant at $p$ <.05.

immaturity illness would be relatively greater than the contribution of the quality of the infant environment.

The full explanatory model and the path coefficients obtained through LISREL analysis are presented in Figure 6. The goodness-of-fit measure for the model was very good (1.000, adjusted to 1.000) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 1.00 (*df* = 4, *p* = 1.00), also indicating a very good fit of the model. Three of the four predicted paths produced significant path coefficients. Although the measures of fit indicated a very good fit between the model and the data, the model as a whole was not supported because one of the paths were not significant. Therefore, the nonsignificant path between motor outcome and immaturity/illness was fixed at zero and the model was then retested.

The revised explanatory model and the path coefficients are presented in Figure 7. The goodness-of-fit measure for the model was acceptable (.987, adjusted to .974) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 2.32, (*df* = 5, *p* = .803), also indicating a good fit. Subtracting the chi-square and degrees of freedoom of the full model from those of the reduced model, following the procedure for nested models, yields a nonsignificant chi-square of 2.31 (*df* = 1). (Hayduk, 1987). Therefore the full model did not represent a significantly better fit to the data than the reduced model, that showed the measure of immaturity/illness to have

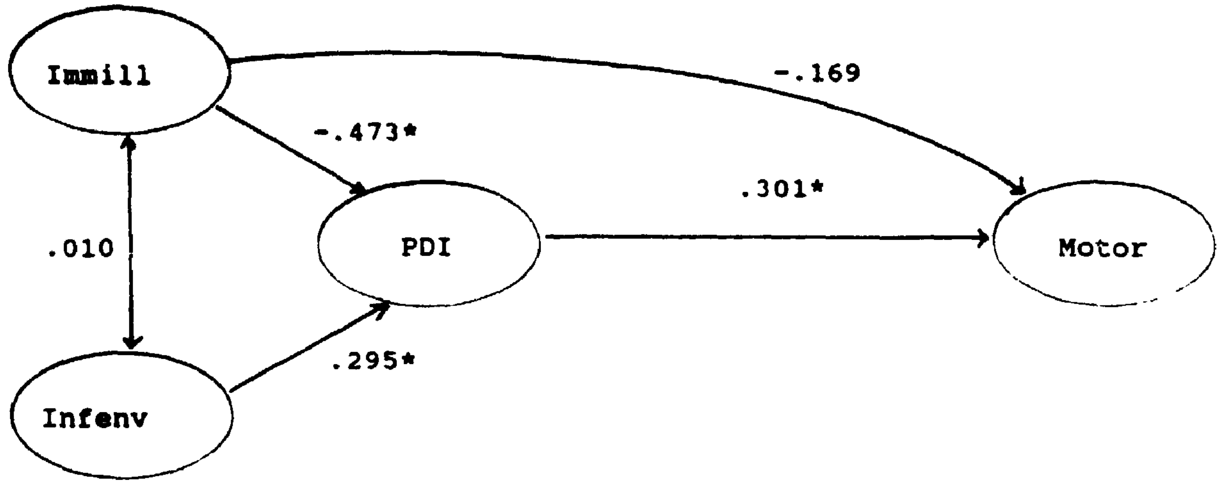


Figure 6. Explanatory model of motor outcome and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index.

Coefficients with an asterisk are significant at p <.05.

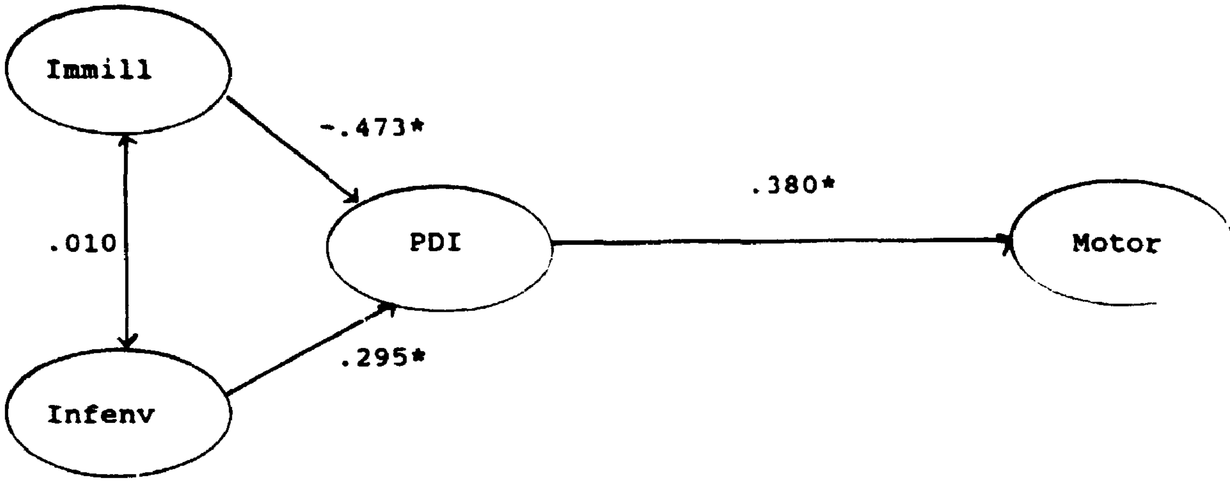


Figure 7. Revised explanatory model of motor outcome and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index.

Coefficients with an asterisk are significant at $p < .05$.

an effect on motor outcome through an indirect path, via infant psychomotor development.

At the level of individual equations, the results are as follows: for infant developmental status (Bayley PDI), $R^2 = .310$; for motor outcome, $R^2 = .145$. At the level of specific predictive paths between variables, all of the hypothesized path coefficients were significant at the $p < .05$ value. Immaturity/illness had a negative influence on infant developmental status ($B = -.473$, $t = -5.33$) that, in turn, had a positive influence on motor outcome ($B = .380$, $t = 3.86$). The quality of the infant environment had a positive influence on infant developmental status ($B = .295$, $t = 3.38$).

The model supported indirect effects of immaturity/illness and the quality of the infant environment, through infant psychomotor development on child motor outcome. The direct effects, indirect effects and total effects of each predictor on motor outcome are presented in Table 27. Immaturity/illness had an indirect effect (-.180) on motor outcome. The quality of the infant environment also had an indirect effect (.112). Infant psychomotor development had a direct effect on motor outcome (.380).

Attention outcomes

Separate models of the development of inattention, impulsivity and hyperactivity were formulated and evaluated. Although measures of inattention, impulsivity and

Table 27

Indirect, direct and total effect coefficients for motor outcome.

| | Effect coefficient | | |
|---|---|---|---|
| Variable | Indirect | Direct | Total |
| Immill | -.180 | --- | -.180 |
| Infenv | .112 | --- | .112 |
| PDI | --- | .380 | .380 |

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index.

hyperactivity were intercorrelated, there were both conceptual and empirical reasons for formulating these separate models. The conceptual, definitional, and methodological problems that have been associated with identifying and explaining attention problems among low birthweight children suggested that it might be useful to distinguish between the different aspects of this area of functioning. In this way, the relative contribution of medical risk and environmental factors for each aspect of attention could be spe'ified. For example, the quality of the child environment, that might influence the child's ability to regulate attention during cognitive tasks, might be relatively more important to inattention and impulsivity (Palfrey et al., 1985; Tobey & Schraeder, 1990). However, immaturity/illness, as a marker for biological or maturational factors, might be relative more important in explaining individual differences in hyperactivity during childhood (Breslau et al., 1988; Szatmari et al., 1990). In addition, multiple regression analyses had indicated that the best prediction equation was different for each aspect of attention. Therefore, each of these models was evaluated in turn.

Inattention. The hypothesized model of inattention and the zero order correlations between the components of the model are presented in Figure 8. The predictors were those measures used in the multiple regression analyses: the aggregate measures of immaturity/illness and the quality of

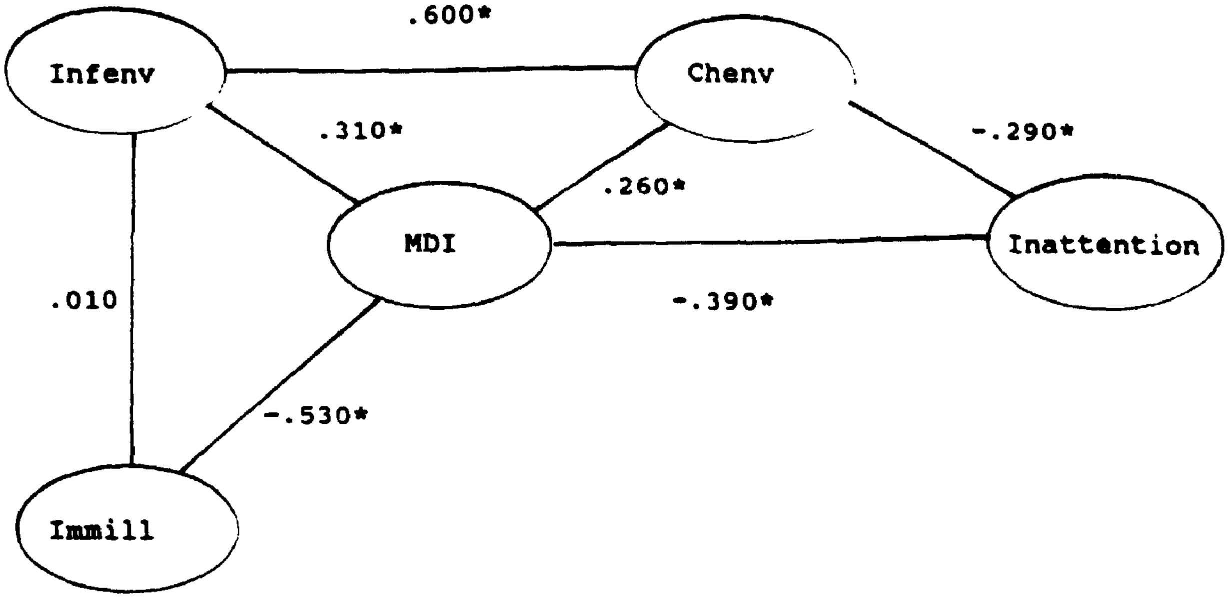


Figure 8. Explanatory model of inattention and zero order correlation coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p < .05$.

the infant environment; the Bayley MDI score; and the measure of the quality of the home environment. The outcome measure was the aggregate measure of child inattention.

It was hypothesized that immaturity/illness would make an indirect contribution, via infant developmental status (Bayley MDI); that the quality of the infant environment would make an indirect contribution, via infant developmental status (Bayley MDI) and the quality of the child environment; that infant developmental status (Bayley MDI) would make a direct contribution and an indirect contribution, via the quality of the child environment; and that the quality of the child environment would make a direct contribution to child inattention.

The full explanatory model and the path coefficients obtained through LISREL analysis are presented in Figure 9. The goodness-of-fit measure for the model was acceptable (.994, adjusted to .985) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 1.27 ($\underline{df}$ = 6, $\underline{p}$ = .973), also indicating a good fit of the model. Five of the six predicted paths produced significant path coefficients. Although the measures of fit indicated an acceptable fit between the model and the data, the model as a whole was not supported because one of the paths was not significant. Therefore, the nonsignificant path between infant developmental status and the quality of the child environment was fixed at zero and the model was retested.

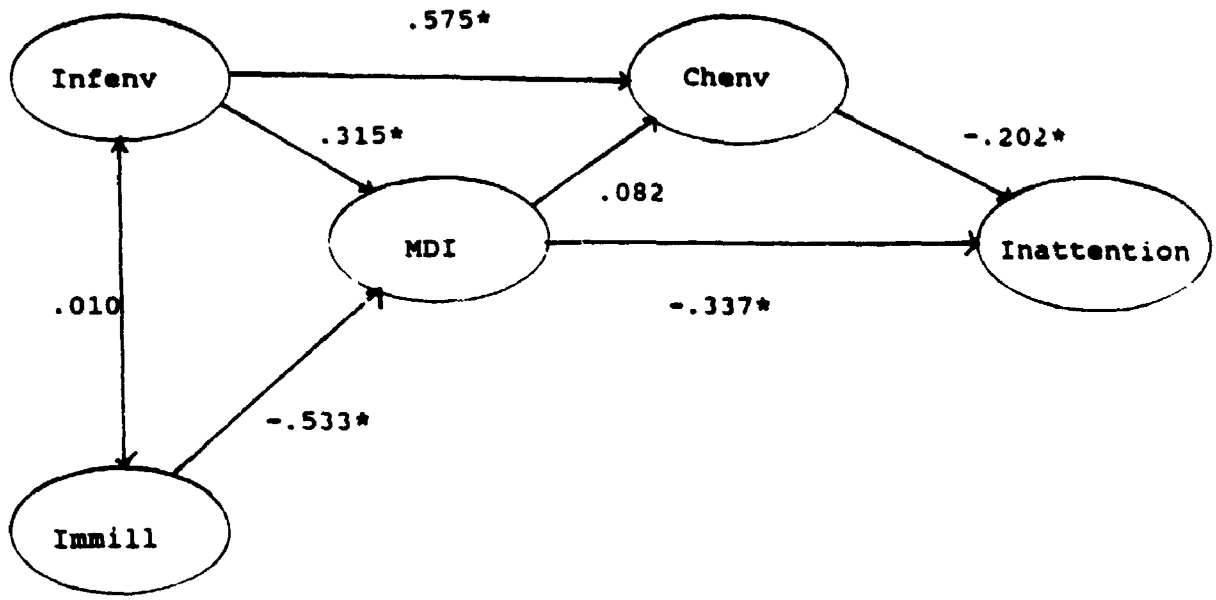


Figure 9. Explanatory model of inattention and path coefficients.
Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p < .05$.

The revised explanatory model and the path coefficients are presented in Figure 10. The goodness-of-fit measure for the model was acceptable (.990, adjusted to .980) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 2.11, (*df* = 7, *p* = .954), also indicating a good fit. Following the procedure for nested models, the difference between the chi-square statistics and the degrees of freedom for the full and the revised models yields a nonsignificant chi-square of .84 (*df* = 1) (Hayduk, 1987). Therefore, the full model did not represent a significantly better fit to the data than the reduced model.

At the level of individual equations, the results are as follows: for infant developmental status (Bayley MDI), $R^2$ = .382; for quality of the child environment, $R^2$ = .360; for inattention, $R^2$ = .183. At the level of specific predictive paths between variables, all five of the hypothesized path coefficients were significant at the *p* <.05 value. Immaturity/illness had a negative influence on infant developmental status (P = -.533, *t* = -6.35) that, in turn, had an inverse effect on inattention (B = -.337, *t* = -3.46). The quality of the infant environment had a positive influence on infant developmental status (B = .3[illegible] *t* = 3.76), and the quality of the child environment (B = .600, *t* = 7.04). The quality of the child environment had an inverse effect on child inattention (B = -.202, *t* = -2.07).

The model supported direct effects of infant developmental status and the quality of the child

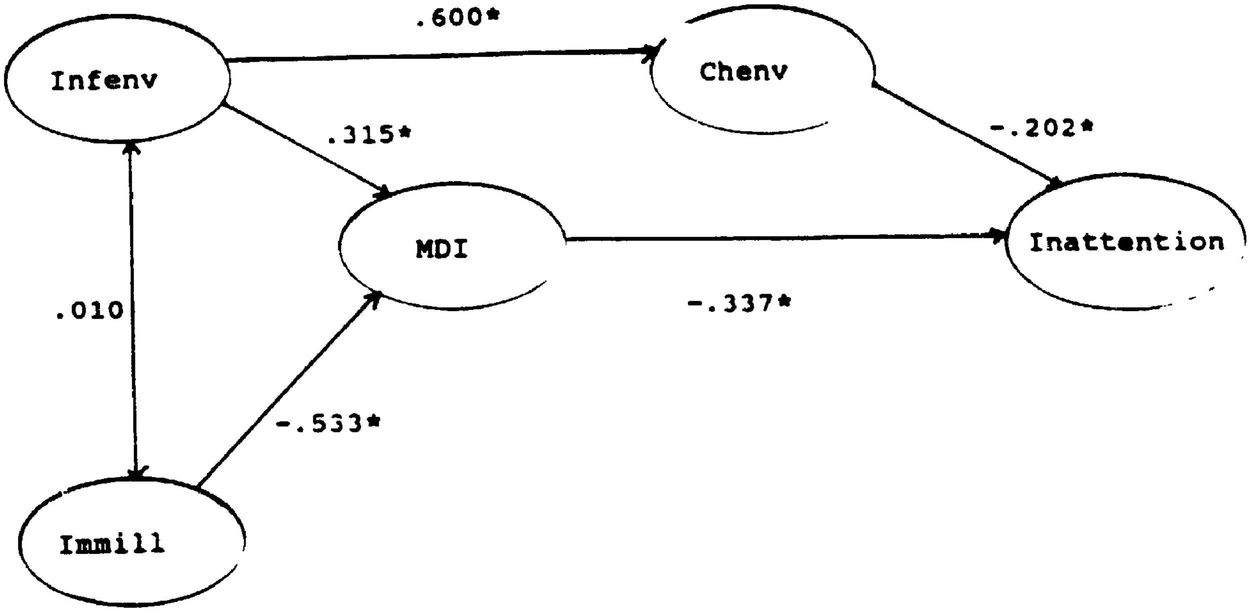


Figure 10. Revised explanatory model of inattention and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p < .05$.

environment on child inattention. The model supported indirect effects of immaturity/illness and the quality of the infant environment on child inattention. The direct effects, indirect effects and total effects of each predictor on language outcome are presented in Table 28. Immaturity/illness had an indirect effect, via infant mental development (.180). The quality of the infant environment had an indirect, via infant mental development (-.228). Infant developmental status had a direct effect on inattention (-.337), as did the quality of the child environment (-.202).

Impulsivity. The hypothesized model of impulsivity and the zero order correlations between the components of the model are presented in Figure 11. The predictors were those measures used in the multiple regression analyses: the aggregate measures of immaturity/illness and the quality of the infant environment; the Bayley MDI and PDI scores; and the measure of the quality of the home environment. The outcome measure was the aggregate measure of child impulsivity.

It was hypothesized that immaturity/illness would make an indirect contribution, via infant developmental status (Bayley MDI and PDI), to childhood impulsivity; that the quality of the infant environment would make an indirect contribution, via infant developmental status (Bayley MDI and PDI); that infant psychomotor development would make a direct contribution and an indirect contribution, via infant

Table 28

Indirect, direct and total effect coefficients for inattention outcome.

| | Effect coefficient | | |
| --- | --- | --- | --- |
| Variable | Indirect | Direct | Total |
| Immill | .180 | --- | .180 |
| Infenv | -.228 | --- | -.228 |
| MDI | --- | -.337 | -.337 |
| Chenv | --- | -.202 | -.202 |

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version.

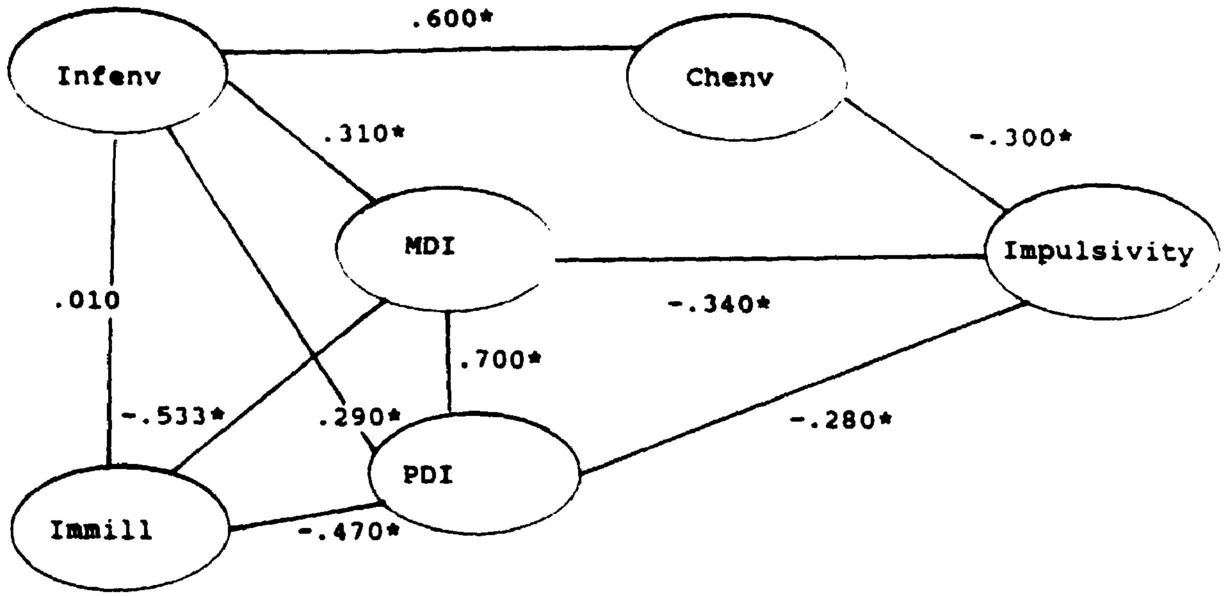


Figure 11. Explanatory model of impulsivity and zero order correlation coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p < .05$.

mental development; that infant developmental status (Bayley MDI and PDI) would make a direct contribution; and that the quality of the child environment would make a direct contribution to child impulsivity.

The full explanatory model and the path coefficients obtained through LISREL analysis are presented in Figure 12. The goodness-of-fit measure for the model was acceptable (.980, adjusted to .948) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 5.30 (*df* = 8, *p* = .726), also indicating a good fit of the model. Seven of the 8 predicted paths produced significant path coefficients. Although the measures of fit indicated an acceptable fit between the model and the data, the model as a whole was not supported because one of the paths was not significant. Therefore, the nonsignificant path between infant psychomotor development and impulsivity was fixed at zero and the model was retested.

The revised explanatory model and the path coefficients are presented in Figure 13. The goodness-of-fit measure for the model was acceptable (.978, adjusted to .949) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = 5.80, (*df* = 9, *p* = .760), also indicating a good fit. Subtracting the chi-square and degrees of freedom of the full model from those of the reduced model, following the procedure for nested models, yields a nonsignificant chi-square of .50 (*df* = 1) (Hayduk, 1987). Therefore the

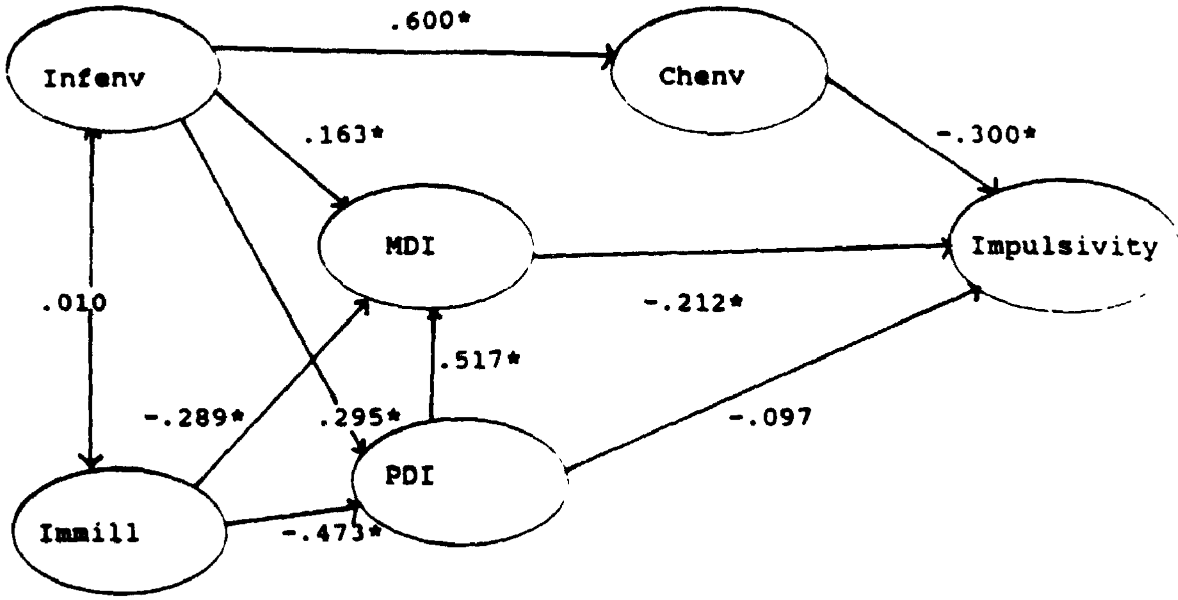


Figure 12. Explanatory model of impulsivity and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p$ <.05.

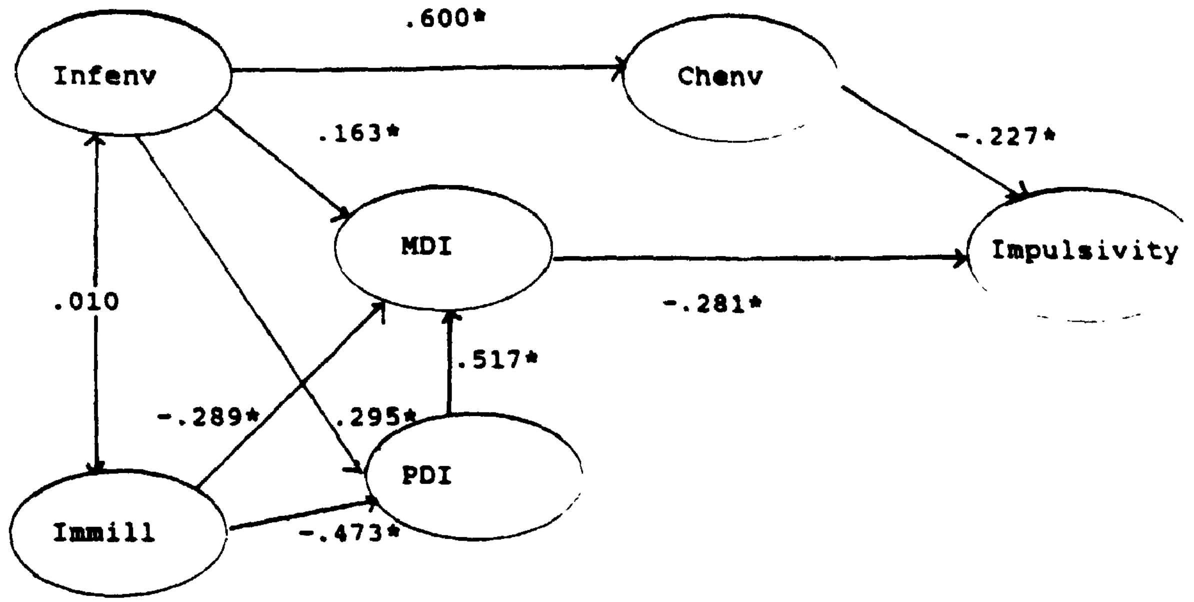


Figure 11. Revised explanatory model of impulsivity and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; MDI=12 month uncorrected Bayley Mental Development Index; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version Coefficients with an asterisk are significant at $p \leq .05$.

full model did not represent a significantly better fit to the data than the reduced model.

At the level of individual equations, the results are as follows: for infant mental development (Bayley MDI), $R^2$ = .567; for infant psychomotor development (Bayley PDI, $R^2$ = .310; for quality of the child environment, $R^2$ = .360; for impulsivity, $R^2$ = .156. At the level of specific predictive paths between variables, all 8 of the hypothesized path coefficients were significant at the $p$ <.05 value. Immaturity/illness had a negative influence on infant psychomotor development (B = -.473, $t$ = -5.33) that, in turn, had a positive effect on infant mental development (B = -.517, $t$ = 6.12). Immaturity/illness also had anegative influence on infant mental development (B = -.289, $t$ = -3.57), that, in turn, had an inverse effect on childhood impulsivity (B = -.281, $t$ = -2.84). The quality of the infant environment had a positive influence on infant mental development (B = .163, $t$ = 2.19), infant psychomotor development (B = .295, $t$ = 3.32), and the quality of the child environment (B = .600, $t$ = 7.04). The quality of the child environment had an inverse effect on child impulsivity (B = -.227, $t$ = -2.29).

The model supported direct effects of infant mental development and the quality of the child environment on child impulsivity and indirect effects of immaturity/illness, infant psychomotor development, and the quality of the infant environment on child impulsivity. The direct effects, indirect effects and total effects of each predictor on impulsivity are presented in Table 29. Immaturity/illness had an indirect effect (.150) through infant psychomotor and mental development. The quality of the infant environment had an indirect effect (-.225) through measures of infant development and the quality of the child environment. Infant psychomotor development had an indirect effect (-.145), through infant mental development. Infant mental development had a direct effect (-.281), as did the quality of the child environment (-.227).

Hyperactivity. The hypothesized model of hyperactivity and the zero order correlations between the components of the model are presented in Figure 14. The predictors were those measures used in the multiple regression analyses: the aggregate measures of immaturity/illness and the quality of the infant environment; and the Bayley PDI score. The outcome measure was the aggregate measure of child hyperactivity.

It was hypothesized that immaturity/illness would make an indirect contribution, via infant psychomotor development (Bayley PDI), to childhood hyperactivity; that the quality of the infant environment would make an indirect contribution, via infant psychomotor development (Bayley PDI) and the quality of the child environment; that infant psychomotor development (Bayley PDI) would make a direct

Table 29

Indirect, direct and total effect coefficients for impulsivity outcome.

| | Effect coefficient | | |
|---|---|---|---|
| Variable | Indirect | Direct | Total |
| Immill | .150 | --- | .150 |
| Infenv | -.225 | --- | -.225 |
| PDI | -.145 | --- | -.145 |
| MDI | --- | -.281 | -.281 |
| Chenv | --- | -.227 | -.227 |

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index; MDI=12 month uncorrected Bayley Mental Development Index; CHENV= Total HOME Inventory score, early childhood version.

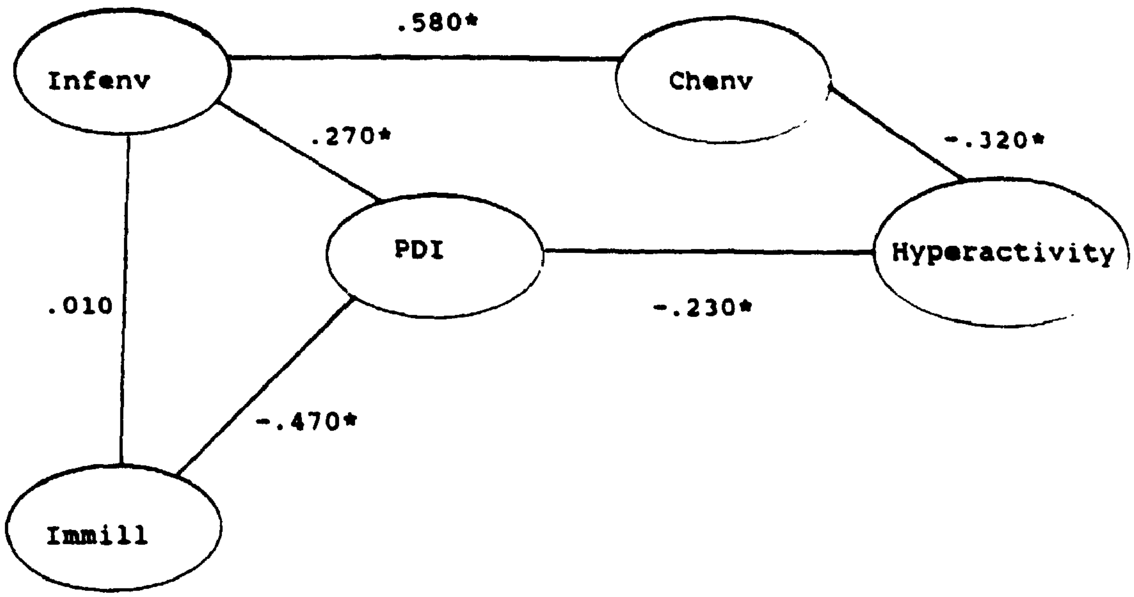


Figure 14. Explanatory model of hyperactivity and zero order correlation coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version

Coefficients with an asterisk are significant at $p < .05$.

contribution; and that the quality of the child environment would make a direct contribution to child hyperactivity.

The full explanatory model and the path coefficients obtained through LISREL analysis are presented in Figure 15. The goodness-of-fit measure for the model was acceptable (.996 adjusted to .991) and the chi-square goodness-of-fit measure was nonsignificant, chi-square = .89 (*df* = .89, *p* = .996), also indicating a good fit of the model. All five of the predicted paths produced significant path coefficients. Therefore the full model did not need to be revised.

At the level of individual equations, the results are as follows: for infant psychomotor development (Bayley PDI, $R^2$ = .312; for quality of the child environment, $R^2$ = .336; for hyperactivity, $R^2$ = .138. At the level of specific predictive paths between variables, all five of the hypothesized path coefficients were significant at the *p* <.05 value. Immaturity/illness had a negative influence on infant psychomotor development (B = -.482, *t* = -5.42) that, in turn, had an inverse effect on hyperactivity (B = -.186, *t* = -1.86). The quality of the infant environment had a positive influence on infant psychomotor development (B = .289, *t* = 3.25, and the quality of the child environment (B = .580, *t* = 6.68). The quality of the child environment had an inverse effect on child hyperactivity (B = -.292, *t* = -2.91).

The model supported direct effects of infant psychomotor development and the quality of the child

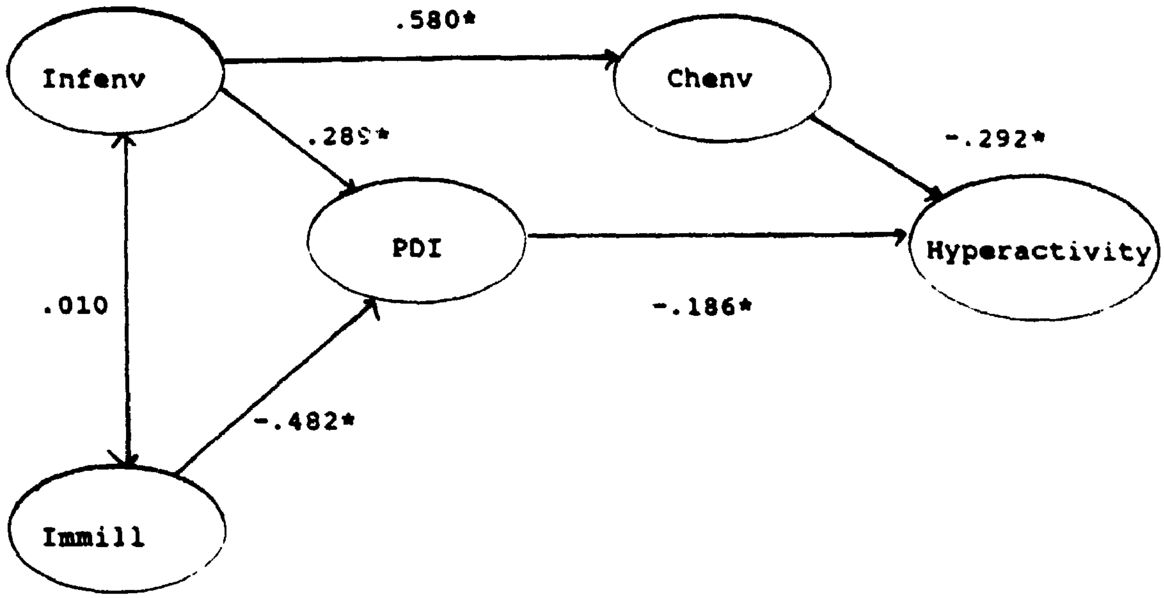


Figure 15. Explanatory model of hyperactivity and path coefficients.

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version

Coefficients with an asterisk are significant at $p$ <.05.

environment on child hyperactivity. The model supported indirect effects of immaturity/illness and the quality of the infant environment on child hyperactivity. The direct effects, indirect effects and total effects of each predictor on hyperactivity are presented in Table 30. Immaturity/illness had an indirect effect on hyperactivity (.090) via infant psychomotor development, as did the quality of the infant environment (-.223). Infant psychomotor development had a direct effect (-.186), as did the quality of the child environment (-.292).

Table 31 presents and contrasts the total effects of immaturity/illness, infant environmental factors, infant developmental status and concurrent child environmental factors for the specific aspects of childhood functioning. The models that were supported by the LISREL analyses indicated that the total effects of each predictor on childhood outcome varied for the different aspects of childhood functioning.

Table 30

Indirect, direct and total effect coefficients for hyperactivity outcome.

| Variable | Effect coefficient Indirect | Direct | Total |
|---|---|---|---|
| Immill | .090 | --- | .090 |
| Infenv | -.223 | --- | -.223 |
| PDI | -.186 | --- | -.186 |
| Chenv | --- | -.292 | -.292 |

Note. IMMILL=Aggregate measure of immaturity/illness; INFENV=Aggregate measure of the quality of the infant environment; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version.

Table 31

Total effect coefficients for language, motor and attention outcomes.

| | Outcome | | | | |
|---|---|---|---|---|---|
| Variable | Lang | Motor | Inatt | Imp | Hype |
| Immill | -.193 | -.180 | .180 | .150 | .090 |
| Infenv | .216 | .112 | -.228 | -.225 | -.223 |
| Infses | .309 | --- | --- | --- | --- |
| MDI | .362 | --- | -.337 | -.281 | --- |
| PDI | --- | .380 | --- | -.145 | -.186 |
| Chenv | .193 | --- | -.202 | -.227 | -.292 |
| Matvocab | .377 | --- | --- | --- | --- |

Note.

LANG=Language outcome measure; MOTOR=Motor outcome measure; INATT=Inattention outcome measure; IMP=Impulsivity outcome measure; HYPE=Hyperactivity outcome measure.

IMMILL=Aggregate measure of immaturity/Illness; INFENV=Aggregate measure of the quality of the infant environment; INFSES=Aggregate measure of infant socioeconomic status; MDI=12 month uncorrected Bayley Mental Development Index Score; PDI=12 month uncorrected Bayley Psychomotor Development Index; CHENV= Total HOME Inventory score, early childhood version; MATVOCAB=Maternal PPVT-R score.

## Discussion

Overview. The results of the path analyses are consistent with several general expectations. First, the data support models of development among low birthweight infants in which there are multiple influences on childhood outcome, confirming transactional, rather than linear, models of the relation between early medical risk and subsequent outcome. Second, the data support models in which the relative contributions of medical risk and environmental factors are different for language, motor and attention outcomes. Finally, the utility of identifying different aspects of attention outcome is supported. In other words, the relative contributions of medical risk and environmental factors may vary for different aspects of a particular childhood outcome, as well as across different outcomes. The results of these analyses will be discussed and a general discussion of the findings and conclusions of the present study will then be presented.

Multiple effects on childhood outcome.

Path analyses confirm that both child characteristics and environmental factors contribute to childhood outcomes, and identify the contribution of factors that were not selected as significant predictors in regression analyses. Medical risk has an effect on all childhood outcomes, although immaturity/illness was not selected as a predictor of language, inattention, impulsivity or hyperactivity in regression analyses. Similarly, infant environmental factors have an effect on all childhood outcomes, despite the prominence of child environmental factors in the results of prediction analyses. The effect of medical risk on all childhood outcomes is indirect and via a measure of infant developmental status. Similarly, the contributions of infant environmental factors are indirect, via measures of either infant developmental status or child environmental factors. There is a direct effect of infant developmental status on all childhood outcomes and direct effects of child environmental factors on language and attention outcomes. The results of these analyses, then, are illustrative of multiple effects on development and suggestive of underlying developmental processes.

These results support a multivariate model of language. Both medical risk and the quality of the infant environment contribute directly to infant mental development, that, along with general stimulation of cognitive development and specific stimulation of language (via maternal vocabulary), contribute directly to childhood language skills. Optimal cognitive functioning during infancy, then, is directly influenced by a lower level of medical risk and sensitive and appropriate caregiving during infancy, and indirectly influenced by higher socioeconomic status. Optimal language outcome during childhood, then, is influenced indirectly by medical risk and infant environmental factors and directly by both level of functioning during infancy, and the quality of stimulation in the childhood environment.

These results also support a multivariate model of motor outcome, although the model is relatively simpler than the models of language and attention outcomes. Both medical risk and the quality of the infant environment had a direct effect on infant psychomotor development, that in turn, was directly related to childhood motor outcome. Optimal motor outcome, then, is indirectly influenced by lower levels of medical risk and by appropriate stimulation and caregiving during infancy, and directly influenced by level of psychomotor functioning during infancy.

Finally, these results demonstrate the utility of a multivariate model of attention outcomes. Problems of sustained attention to challenging tasks during childhood are influenced indirectly by early medical risk and the quality of the infant environment, and are directly related to performance during developmental testing during infancy. Problems of impulsivity, difficulty in inhibiting premature and disorganized responses during challenging tasks, may have both an attentional and a motor component. Medical risk and the quality of the infant environment directly influence both infant mental and psychomotor development. There is a direct contribution of infant mental development and an indirect contribution of infant psychomotor immaturity. Impulsivity may also be indirectly influenced by the quality of the caretaking environment during infancy. Hyperactivity during childhood may have a substantial motor component. Problems of excessive and inappropriate motor activity during childhood are influenced indirectly by medical risk and the quality of the infant environment, and may be directly influenced by infant psychomotor immaturity. Inattention, impulsivity and hyperactivity are all directly influenced by the sensitivity and appropriateness of stimulation provided by the caretaker during childhood.

Therefore, these analyses support models of developmental outcome in which the relation between early medical risk and subsequent outcome is an indirect one. Intervening factors, such as the quality of the infant environment, infant development, and the quality of the child environment are also related to childhood outcomes and influence the effect of medical risk. The relations between early medical risk and subsequent outcome, then, can be represented by a network of factors that contribute both directly and indirectly to language, motor, and attention skills during childhood.

Different effects across outcomes.

The relative contributions of medical risk, infant environmental factors, infant developmental status, and childhood environmental factors are different for language, motor and attention outcomes. Environmental factors make a substantial contribution to language outcome and a relatively greater contribution to language outcome than does immaturity/illness. However, both immaturity/illness and infant developmental status have an effect on language outcome. In contrast, the contribution of environmental factors to motor outcome is relatively less than the contribution of immaturity/illness. However, the quality of the infant environment makes an indirect contribution to childhood motor outcome as a result of its modest but direct effect on infant psychomotor development. Finally, environmental factors make a relatively greater contribution to childhood inattention, impulsivity and hyperactivity than does immaturity/illness. However, the effect of immaturity/illness is via infant developmental status, that makes an important contribution to all of these childhood outcomes.

Immaturity/illness. Medical risk makes a significant indirect contribution, via infant mental and psychomotor development, to language, motor and attention outcomes. The total effect of immaturity/illness is relatively greater for language, motor and and inattention outcomes than for impulsivity and hyperactivity.

In the present study, optimal language outcome is indirectly associated with lower levels of medical risk. The measure of immaturity/illness may serve as a marker for a biological or maturational component of language development (Largo et al., 1986; Siegel, 1979, 1981), an interpretation that is supported by the associations between immaturity/illness and two environmental measures that may reflect genetic influences -- maternal vocabulary and socioeconomic status. Alternatively, the relation between immaturity/illness and subsequent language may be due to the relations between both these measures and the measure of infant mental development.

Immaturity/illness appears to have a slightly greater effect on motor outcome than on language, as environmental factors are prominent in the model of language outcome. As in the case of language, immaturity/illness makes only an indirect contribution, via infant psychomotor development, to childhood motor outcome, although the direct path coefficient between these two components of the model approaches a statistically significant level in the full model. There are several factors that may account for the indirect contribution of immaturity/illness. First, this contribution may reflect a maturational component of motor development that is still evident during early childhood. Second, this effect may be due to the consequences of insult to the central nervous system that is related to immaturity and illness during the neonatal period but is also reflected in motor skills during both infancy and early childhood. This interpretation is consistent with the suggestions of previous research, that have suggested an underlying continuity between medical risk and later motor development (Crowe et al., 1988). Therefore, the findings of the current study are consistent with the suggestion that there may be greater stability of motor development relative to other aspects of functioning (Aylward et al., 1987), due to the influence of genetic, maturational, and biological factors that may be represented by the measure of immaturity/illness. Alternatively, these findings may be attributable to a relatively smaller influence of environmental factors on child motor functioning.

The results of the current study do not support a direct relation between early medical risk and later attention problems. Rather, the effect of medical risk is indirect and via measures of infant mental and psychomotor development. This finding is consistent with the conclusions of reviews of the prospective research literature that report weak relations between medical risk and subsequent attention problems and relatively stronger relations between environmental factors and these problems (Rapoport & Ferguson, 1981). However, this finding is not consistent with the conclusions of the limited number of reports of influences on attention problems among low birthweight children (Breslau et al., 1988; Calame, et al., 1986; Szatmari, et al., 1990), that have strongly suggested a direct relation between medical risk and childhood attention problems.

One reason for the contrast between the findings of the current study and these earlier reports on low birthweight children may be differences in sample characteristics, as well as differences in conceptualization of environmental influences. For example, Szatmari et al. (1990) explicitly challenged the notion that environmental factors are an important influence on attention problems and reported data in support of their view. However, their study sample consisted of extremely low birthweight children (<1000 g) and the generalizability of their conclusions to more heterogeneous samples, such as the sample in the current study, may be limited. This limitation is supported by other discussions of influences on attention problems, that have suggested that there may be some children for whom environmental influences may not compensate for early medical risk (Rapoport & Ferguson, 1981). Furthermore, Szatmari et al. (1990) did not consider possible indirect effects of environmental factors, via developmental measures, on attention problems.

Therefore, across all outcomes, the effect of immaturity/illness is indirect. The effect of immaturity/illness on language outcome is indirect but may be equivalent to the effect on motor outcome and relatively greater than the effect on most attention outcomes. Its contribution to language, motor and inattention outcomes is relatively greater than its contribution to impulsivity and hyperactivity. There are several possible explanations for these findings. The contribution of immaturity/illness to language may reflect biological or genetic contributions to this aspect of child functioning. Immaturity/illness may reflect an important maturational component of language and motor functioning that is still evident during early childhood. Alternatively, immaturity/illness may reflect insult to the central nervous system that influences motor functioning and sustained attention abilities. Although the models of impulsivity and hyperactivity support a motor component for each of these aspects of attention, the contribution of immaturity/illness is not as great as in the case of inattention, nor as great as the contribution of environmental factors. It may be, therefore, that the quality of caretaking may influence the child's ability to control or regulate impulsive behaviour and excessive motor activity. This interpretation has been supported by other prospective accounts of the development of attention problems (Jacobvitz & Sroufe, 1987), as well as by prospective reports in the clinical literature (Campbell, 1985).

Infant environmental factors. Infant environmental factors make a substantial indirect contribution to all childhood outcomes. Infant socioeconomic status makes a contribution to child language and the quality of the infant environment makes an indirect contribution to all childhood outcomes, although its effect on language and attention outcomes is relatively greater than its effect on motor outcome.

Socioeconomic status represents an important contribution to child language, possibly due to its association with immaturity/illness or its relation with other important environmental influences. One component of the measure of infant socioeconomic status, maternal education, is also associated with both the provision of general stimulation of cognitive development and level of maternal vocabulary. The indirect effect of infant socioeconomic status is consistent with previous reports that have suggested that its effect on childhood outcomes may be mediated in part by the quality of caregiving (Luster & Dubow, 1991).

The quality of the infant environment demonstrates a substantial, but indirect effect on childhood language. Therefore, although there may not be a direct effect of stimulating and appropriate caregiving during infancy for childhood language, the quality of the infant environment makes a direct contribution to infant mental development, that in turn, makes an important contribution to subsequent language outcome. Alternatively, continuity in the provision of appropriate and stimulating caregiving may contribute to optimal language functioning during childhood.

Environmental factors do not represent important influences on childhood motor functioning. The absence of a relation between childhood motor skills and socioeconomic status during infancy suggests that measures of socioeconomic status in the current study may not reflect biological or genetic factors that are directly related to concurrent motor functioning. However, the results of the current study are consistent with the suggestion that correlates of socioeconomic status may influence motor outcome (Klein et al., 1985). Socioeconomic status during infancy was significantly correlated with the quality of the infant environment, that in turn makes an indirect contribution to childhood motor outcome. It is important to note, therefore, that the quality of the infant environment makes an indirect contribution to levels of motor functioning during childhood.

There are several possible interpretations of these results concerning motor outcome. The relation between the quality of the infant environment and infant psychomotor development suggests that the caregiver's sensitivity to the infant's developmental level, as well as the provision of appropriate experiences (opportunities for gross motor activity) and play materials (opportunities for fine motor activity and the manipulation of objects), may enhance motor development during infancy. The Bayley PDI at 12 months represents a general evaluation of motor skills that is comprised of fine motor skills (grasping and releasing of objects) that will influence performance on mental scale items, as well as major milestones in gross motor development (independence in sitting and walking). One can speculate that, relative to cognitive milestones such as object permanence or problem solving, the achievement of milestones in motor development during infancy may represent an obvious marker of appropriate or inappropriate development, as well as obvious opportunities for stimulation. Therefore, these results are in contrast to those of previous reports that have dismissed the influence of environmental factors on childhood motor development

(Aylward et al., 1988; Marlow et al., 1989). Rather, motor functioning may be less readily influenced by the physical and social environment than is functioning in other areas such as language (Wallace et al., 1982).

These results suggest that motor skills may be relatively more negatively influenced by medical risk (Mazer et al., 1988) than are other childhood outcomes. Alternatively, there may be limits on the effects of the quality of the environment on motor outcome due to constraints set by central nervous system damage that may coincide with low birthweight. Therefore, this view suggests a contribution of environmental factors for motor outcome that is relatively less important than immaturity/illness. Although minimal environmental influences may be required in order to facilitate motor development, optimal development may be associated with lower levels of environmental risk, and higher levels of appropriate stimulation and caregiving. However, there may be a limit to the facilitating effects of environmental factors on aspects of development, such as motor development, that may be strongly related to biological and maturational factors.

Infant environmental factors have an important role in models of inattention, impulsivity and hyperactivity. These are measures of the quality of the environment, rather than socioeconomic status, and their contributions are indirect. This finding is consistent with previous reports that have concluded that the influence of the quality of the home environment may be relatively more important than that of socioeconomic status (Schiamberg & Lee, 1991; Tobey & Schraeder, 1990).

The quality of the infant environment makes an indirect contribution to childhood inattention via infant mental development and the quality of the child environment. Both less stimulating, less appropriate environments, as well as lower levels of infant mental and psychomotor development are also associated with childhood impulsivity. Similarly, the quality of the infant environment has direct effects on infant psychomotor development and the quality of the child environment, that both make a direct contribution to childhood hyperactivity.

Therefore, during infancy, caretaking that is appropriately stimulating and sensitive to the child's abilities may enhance the development of psychomotor abilities as well as abilities to organize behaviour and inhibit inappropriate responses during structured tasks. These antecedents of childhood attention skills may, therefore, be reflected in measures of infant mental or psychomotor development. Furthermore, continuity in the quality of caretaking between infancy and childhood, as indexed by the direct contribution of the quality of the infant environment to the quality of the child environment, may serve to support developing attention skills or to contribute to attention problems during early childhood. As low birthweight infants may be characterized as possessing relatively limited resources for self organization and self regulation during infancy, variations in the quality of the environment may become an important source of variation in childhood attention outcomes (Rocissano & Yatchmink, 1983).

Infant developmental status. Infant mental development makes a direct contribution to childhood language, inattention and impulsivity. Infant psychomotor development makes a direct contribution to motor outcome and hyperactivity, and an indirect contribution to childhood impulsivity.

The relation between the measure of infant developmental status and child language outcome may be due to several factors. First, there may an underlying continuity in the processes of language development, as there are items reflecting early language skills on the Bayley MDI at 12 months that may serve as important predictors of subsequent language (Siegel, 1979, 1981). These include imitation, receptive language, and expressive language items. Second, the measure of infant developmental status may also reflect the influence of immaturity/illness. Finally, the measure of infant developmental status may also reflect the influences of the quality of the caretaking environment and, indirectly, infant socioeconomic status (Crisafi et al., 1987). The quality and appropriateness of stimulation during infancy influence infant mental development directly, but influence child language indirectly. As there is a strong correlation between measures of the quality of the environment during infancy and during childhood, the quality of the childhood environment can be characterized as contributing to the stability of developmental status between infancy and childhood (Rocissano & Yatchmink, 1983). Therefore, continuity between infant mental development and childhood language outcome may be attributable to the combined effects of immaturity/illness, continuity in underlying processes of language development, and the contribution of environmental factors in maintaining individual differences.

The relation between infant psychomotor development and childhood motor outcome may be due to underlying processes of motor development that are continuous between infancy and childhood, an interpretation that is supported by previous reports of greater stability in motor functioning relative to cognitive functioning among low birthweight children (Aylward et al., 1987). There are items assessing early motor skills on the Bayley PDI at 12 months that may serve as important predictors of subsequent motor outcome (Siegel, 1979, 1981). These include important milestones in fine and gross motor development. Second, the measure of infant psychomotor development may also reflect the influence of maturational factors important to motor development during both infancy and childhood. Finally, the measure of infant developmental status may also reflect the influences of the quality of the caretaking environment and, indirectly, infant socioeconomic status (Crisafi et al., 1987). The quality and appropriateness of stimulation during infancy may influence infant psychomotor development directly, but influence child motor development indirectly. Therefore, continuity between infant psychomotor development and childhood motor outcome may be attributable to the combined effects of immaturity/illness, continuity in underlying processes of motor development, and the contribution of infant environmental differences to individual differences in motor functioning.

The contribution of measures of infant developmental status for childhood attention skills is supported by the current study. There is a direct influence of infant mental development on childhood inattention. There are a number of possible explanations for this relation. First, a measure of infant mental development may make a contribution to childhood inattention as a consequence of its relation to medical risk, as immaturity/illness may be a marker for a biological or maturational factor that influences both infant mental development and childhood inattention. This suggestion, that infant developmental status reflects the indirect effects of medical risk and related central nervous system damage, is supported by the results of previous research (Szatmari et al., 1990; Vohr et al., 1989).

Second, the relation between a measure of infant mental development and childhood inattention may be due to continuity in underlying processes of attention.

Inattentiveness and difficulties in sustained attention during cognitive tasks may be an aspect of child functioning that is continuous between infancy and childhood. This suggestion is supported by the findings of previous research, that have demonstrated notable stability on measures of inattention obtained in infancy and childhood (Astbury et al., 1990; Sigman et al., 1987).

Third, the contribution of infant mental development to childhood attention may be to function as a protective factor. This is a suggestion that receives some support in the literature (Palfrey et al., 1985). In other words, higher levels of cognitive functioning may have a compensatory effect, and minimize the likelihood of significant attention problems.

Finally, infant mental development may make a contribution to childhood inattention as a result of its relation to measures of the quality of the infant environment, as it reflects the indirect effects of sensitive and stimulating caregiving during infancy. This suggestion is supported by previous research that has concluded that one function of sensitive caregiving may be to support the child's developing self-regulatory abilities (Jacobvitz & Sroufe, 1987). Therefore, optimal environmental conditions may support the developing abilities to sustain attention, abilities that may be reflected in performance on measures of infant mental development.

There is also a direct influence of infant mental development on childhood impulsivity. In addition, in contrast to the model of inattention, the data support a model of impulsivity that includes an indirect effect of infant psychomotor development, via infant mental development, on childhood impulsivity. Psychomotor immaturity during infancy may exert an indirect effect on childhood impulsivity. There are a number of possible explanations for this pattern of relations. As in the case of inattention, measures of infant development may make a contribution to childhood impulsivity as a consequence of their relations to medical risk (Szatmari et al., 1990; Vohr et al., 1989). Second, the relation between a measure of infant mental development and childhood impulsivity may be due to the possibility that impulsivity during challenging or structured tasks may be an aspect of child functioning that is continuous between infancy and childhood (Astbury et al., 1990). In addition, the substantial but indirect contribution of psychomotor immaturity during infancy may be the result of an underlying processes of motor and attention development that are continuous between infancy and childhood. Finally, as in the model of inattention, the relation between infant developmental status and childhood impulsivity may be due to their relation to measures of the quality of the infant environment and suggests the importance of sensitive caregiving in the etiology of attention problems (Jacobvitz & Sroufe, 1987).

As in the case of inattention and impulsivity, the direct effect of infant psychomotor development to childhood hyperactivity may be a consequence of its relation to medical risk (Szatmari et al., 1990; Vohr et al., 1989) or the quality of the infant environment (Jacobvitz & Sroufe 1987). Second, the relation between a measure of infant psychomotor development and childhood hyperactivity may be due to continuity in underlying processes. Excessive and inappropriate levels of activity may be an aspect of child functioning that is continuous with psychomotor immaturity during infancy, a suggestion that is supported by previous research that has demonstrated notable stability on measures of all aspects of attention problems obtained in infancy and childhood (Astbury et al., 1990).

Therefore, measures of infant developmental status make a direct contribution to all childhood outcomes, although possible explanations for these effects vary for the different outcomes. Measures of infant developmental status may contribute to language and motor outcomes as a result of continuity in underlying processes of maturation or development. The effect on attention outcomes may be due to individual differences in attention skills that are evident in performance on structured and challenging tasks during both infancy and childhood. Finally, the contribution of measures of infant developmental status to childhood outcomes may be due to their relations with immaturity/illness and infant environmental factors.

_Child environmental factors_. The quality of the child environment makes a direct contribution to language and attention outcomes. In addition, maternal vocabulary makes a direct contribution to child language. Although poor environmental conditions may contribute to motor deficits, it is difficult to demonstrate a concurrent influence of the quality of the environment on motor functioning. Rather the influence of environmental factors on motor development may be a distal one. In other words, current childhood levels of motor functioning may be most strongly influenced by previous experiences and stimulation (as reflected by infant environmental measures), that have provided opportunities for practice and refinement of motor skills.

The results concerning childhood environmental influences on language support several conclusions. Both greater levels of general stimulation of cognitive development (the HOME Inventory) as well as greater levels of direct stimulation of language via the quality of the language environment (maternal vocabulary) are positively associated with language outcome. The relation between maternal vocabulary and child language may be due to several factors. Although maternal vocabulary is characterized as a measure of the quality of the child environment in the present study, it may also indirectly reflect a biological contribution to language outcome. Validity studies have suggested that maternal vocabulary would also be correlated with a measure of intelligence during adulthood (Dunn &

Dunn, 1981), and therefore may represent an indirect effect of biological factors on child language. However, the findings of the current study are consistent with suggestions that the quality of the caretaking environment is not just a reflection of maternal intelligence (Schiamberg & Lee, 1990) and that maternal abilities may make both a direct and indirect contribution to child language (Luster & Dubow, 1991). There are significant and direct pathways between both measures and child language, suggesting that sensitive and appropriate caregiving, as well as direct stimulation of language may contribute to child language (Rocissano & Yatchmink, 1983).

Similarly, the quality of the child environment makes a direct contribution to childhood inattention, impulsivity and hyperactivity. Therefore, both lower levels of infant mental and/or psychomotor development and less stimulating, less appropriate environments are associated with childhood attention problems. Furthermore, the consistent contribution of the quality of the child environment to all aspects of attention suggests the importance of the quality of caretaking in both infancy and childhood to the etiology of attention problems. The quality of the child environment may serve to support developing attention skills or to contribute to attention problems during early childhood. As low birthweight infants may be characterized as possessing relatively limited resources for self organization and self regulation during infancy, variations in the quality of the enviroment during both infancy and childhood may become an important source of variation in childhood attention outcomes (Rocissano & Yatchmink, 1983).

Contributions and limitations of path analysis.

The results of the current study suggest that path analysis represents a potentially useful tool for developmental research, as this approach permits the testing of the transactional models of developmental outcome that have been advocated in research on high risk children (Sameroff & Chandler, 1975) and provides a means of contrasting the effects of early medical risk on different aspects of childhood functioning. These results are also essentially exploratory -- they provide support for several hypotheses suggested by the research literature, but also represent a source of new hypotheses that may be tested in future research. For example, the results of path analyses support the general expectation that the contribution of medical risk may vary across different childhood outcomes. However, do the models of development supported in the current study represent a useful approach to understanding the development of either normal birthweight or extremely low birthweight (<1000 g) children?

In addition to the contributions to our understanding of developmental processes, there are, of course, both conceptual and empirical limitations to the results of the path analyses conducted in the present study. These include the limitations inherent in both path analytic techniques and nonexperimental data sets, as well as limitations specific to the current study and study sample.

Contributions of path analysis to an understanding of general processes of development: Multivariate developmental models. The major focus of the research literature has been an interest in determining the effects of low birthweight for subsequent development. The formulation of such a research question implies, either explicitly or implicitly, an interest in causal relations (Pedhazur, 1982). Due to the nonexperimental nature of this research, however, the task of determining the effect, influence, or contribution of early medical risk to subsequent outcome is fraught with interpretative difficulties. Correlations are only suggestive of causal links. Therefore, causal models of relations among variables that are consistent with the data obtained represent the best available evidence in support of the theory that generated these models (Pedhazur, 1982). Path analyses represents an approach that can accomplish this goal for the developmental researcher, as these techniques permit the researcher to draw inferences from nonexperimental data that cannot be supported by the comparison of mean differences or regression analyses alone (Biddle & Marlin, 1987). In addition to formulating possible causal relations among predictor and outcome variables, path analysis allows one to test possible joint influences on outcomes and to identify both direct and indirect effects among independent, intervening and dependent variables. Finally, path analysis typically includes the formulation of a visual representation of the interrelations of interest. This requirement has the practical advantage of presenting a potentially complex conceptual model in a concrete and accessible manner (Biddle & Marlin, 1987).

All of the features of path analysis make it an extremely valuable approach to investigating the central question in the research literature: What is the relation between low birthweight and subsequent outcome? The medical risk associated with low birthweight certainly represents an important influence in the life of the infant and the family and, as the current study indicates, makes a contribution to several important aspects of childhood functioning. However, one of the primary challenges of the research literature has been, and will continue to be, the task of identifying the specific effects of medical risk and distinguishing these effects from those of other important factors that may coexist or correlate with medical risk (Goldberg & DiVitto, 1983; Kalmar, 1987). The limited utility of simple cause/effect models of the relation between early medical risk and subsequent outcome has been demonstrated in the low birthweight literature, as has the need for more complex models of the relation between early events and subsequent outcome (Goldberg & DiVitto, 1983). Furthermore, identifying the joint effects of medical risk and environmental risk has both conceptual and practical interest (Sameroff & Chandler, 1975). Therefore, statistical methods such as path analysis provide an estimate of the effects of multiple factors and represent a useful approach to investigating and identifying multiple effects on developmental outcomes among low birthweight children.

The results of the path analyses may also contribute to our understanding of normal processes of development. As research on low birthweight children has been conceptualized as a prototype for understanding the relative influences of biological and envioronmental factors on development, the results of the current study are suggestive. Just as normal processes of development have been characterized as a consequence of the joint contributions of child characteristics and environmental factors, the models supported in the current study may represent one of many developmental pathways to optimal outcome during childhood. Although medical risk makes an important contribution to childhood outcomes, the joint effects of medical risk and the infant environment are important to infant developmental status. Similarly, both infant developmental status and the quality of the child environment contribute to individual differences in functioning during childhood. The relation between the processes suggested by models in the current study and processes of development among normal birthweight children remains an empirical question, however, and represents a direction for future research.

<u>Contributions of path analysis to an understanding of specific processes of development: Language, motor and attention outcomes</u>. Developmental outcomes are complexly determined (Horowitz, 1987) and the task of accounting for these developmental outcomes is equally complex (Goldberg & DiVitto, 1983). In this regard, Horowitz (1987) has presented and discussed a refinement of the concept of transactional models of development and suggested that environmental influences on development may vary for different aspects of functioning. This discussion is particularly relevant to the focus of the path analyses -- determining the relative contributions of medical risk and environmental factors for language, motor and attention outcomes -- and the results of the current study provide support for Horowitz's suggestion for greater specifity in models of development. Therefore, a brief summary of Horowitz's analysis will be presented and discussed within the context of the results of the present study.

Horowitz's discussion of models of behavioural development (1987) includes a presentation of two categories of behaviours -- universals and non-universals. There are two subcategories of universal behaviours. The first subcategory of universal behaviours will develop under normal environmental conditions and in all situations, apart from major insult to the integrity of the organism. An example of such universal behaviours include perceptual behaviours and eye-hand coordination. An intact organism and normal environment conditions are all that is required for the expression of these behaviours.

The second subcategory of universal behaviours will also typically occur under normal environmental conditions, but is more vulnerable to the effects of different environmental conditions. Examples of this second subcategory of universal behaviours include locomotion, language learning, and infant sensorimotor skills. These behaviours may require a longer course of development than the first subcategory of universal behaviours, and environmental factors will exert a relatively greater influence on the quality of behaviour and level of development. For example, although sensorimotor development may follow a developmental course that is universal for all infants in typical environments, differences in the quality of the environment may influence the quality of behaviour and level of functioning, as well as influencing how infant developmental status will contribute to subsequent cognitive developmental level (Horowitz, 1987). Therefore, both characteristics of the child and characteristics of the environment are important, as the child's characteristics may influence the functional significance of environmental conditions. Individual differences are then related to child characteristics, variations in the environment, and variations in the joint effects of child characteristics and environmental factors.

Non-universal behaviours include all those behaviours that result from learning opportunities, that are influenced by variations in environmental conditions and cultural context (Horowitz, 1987). Non-universal behaviours may or may not incorporate universal behaviours. Although the sequence of development and content of these behaviours may be genetically influenced or common to all children, behavioural development is regarded as strongly influenced by environmental variations. An example of non-universal behaviours will be the organization and expression of affect (Horowitz, 1987), that may be strongly influenced by environmental and cultural factors.

Environmental factors will have little influence on the occurrence and quality of the first type of universal behaviours, will influence the timing and quality of the second type of universal behaviours, but will represent an important influence on the development and quality of non-universal behaviours. Furthermore, the development of both universal and non-universal behaviours will be the result of the joint effects of child characteristics and environmental factors. Just as behaviours are described along the continuum of universal to non-universal, the child can be described along two continua -- the degree of vulnerability and the degree of impairment -- and environments range from facilitative to nonfacilitative of development.

Language is an aspect of functioning that is thought to be influenced by multiple factors, consisting of both universal and non-universal behaviours (Horowitz, 1987). Although some aspects of language acquisition are influenced by genetic or biological factors, environmental factors will influence level of language competence. Universal elements of language learning would include, first, categorical speech perception and second, the infant's attention to aspects of language and communication during social interactions with the caregiver. Although typical environments would include sufficient stimulation for language behaviours to be expressed, different environments would include substantial variations in the content and level of stimulation, beyond what is simply sufficient. These environmental variations would influence the quality of language functioning. Furthermore, there may be individual differences in the degree to which environmental facilitation is important to language development. Child characteristics -- biological insult or vulnerability to adverse environmental conditions -- may mean that environmental stimulation is relatively more important to optimal development among some children. Therefore, language is determined by multiple influences. There are universal and non-universal components to language behaviour, and the child's level of functioning may be influenced by the joint effects of child characteristics and environmental factors (Horowitz, 1987).

The results of the current study appear to be consistent with this conceptualization of processes underlying language outcome. The model of language confirmed by the path analyses includes a contribution of immaturity/illness, as well as a substantial contribution of variations in the quality of the environment. The contribution of immaturity/illness to language outcome may represent a marker for biologically-based universal components of language. Alternatively, the measure of immaturity/illness may represent a child characteristic -- biological vulnerability, infant behavioural characteristics -- that will influence the functional significance of variations in the quality of the infant environment. These variations in the quality of the infant environment -- a measure that reflected both maternal sensitivity and the provision of an appropriate and stimulating environment -- would also presumably influence the quality of early interactions and the quality of early language. The joint effects of child characteristics and variations in the quality of the infant environment on aspects of early language development would be reflected by a measure of infant development in 12 months. The prominent role of environmental conditions during childhood is consistent with the nature of the language outcome measure, that was comprised primarily of expressive and receptive vocabulary items. Vocabulary may certainly represent an aspect of language development that is heavily comprised of non-universal behaviours. Consistent with Horowitz's analysis, the level of vocabulary could be expected to be heavily influenced by variations in environmental or cultural conditions. These would included provision of general cognitive stimulation and the quality of maternal vocabulary.

With respect to motor development, this aspect of functioning is thought to consist heavily of universal behaviours (Horowitz, 1987). Typical variations in environmental conditions will have little impact on early development, although a facilitative environment may influence the rate of development during infancy and early childhoood. The major influences on early motor development will be genetic or biological. For children with a mild motor delay or impairment, the influence of a facilitative environment on rate and level of functioning may be relatively greater than for children who are either developing normally or are severely impaired. Beyond infancy and early childhood, individual differences in motor skill may become more heavily influenced by environmental factors, as opportunities for skill development may be related to child characteristics, parent attitudes, and cultural context (Horowitz, 1987).

The results of the path analysis appear to be consistent with this conceptualization of processes underlying motor outcome. The important contribution of immaturity/illness to both infant psychomotor development and childhood motor outcome is consistent with Horowitz's conceptualization of this aspect of functioning as consisting heavily of universal behaviours. The contribution of the quality of the infant environment supports the contention that, although variations in environmental conditions may have a minimal impact on early development, a facilitative environment may influence the rate of development and level of functioning among children with a mild motor delay (Horowitz, 1987). Despite considerable variability in infant psychomotor development among children in the current sample, the mean uncorrected PDI score at 12 months was 87.5 (s=16.9), and the mean score corrected for immaturity was 97.5 (s=17.6). These results support the notion that variations in environmental conditions may have an impact among low birthweight children, who may demonstrate a mild delay in psychomotor development during infancy. However, the quality of the child environment did not make a significant contribution to childhood motor outcome, despite the fact that mean scores on both childhood outcome measures were below the population mean. This finding suggests that there may be some constraints on the facilitative effect of the environment on motor development during infancy and early childhood, and these influences may be more important to major milestones in gross and fine motor development during infancy than to level of motor skills during early childhood. The nonsignificant impact of variations in environmental conditions during childhood may also be consistent with the nature of the motor outcome measures. These included measures of gross motor skills (throwing, catching, balancing) that may be influenced by experience and practice, and fine motor skills (drawing and copying tasks) that are practiced and refined as the child becomes increasingly involved in the formal educational system, and may represent aspects of motor development that are heavily influenced by experiences that become more common during middle childhood. Therefore, this result is consistent with Horowitz's suggestion that environmental influences on motor development may become most important during middle childhood, when opportunities for skill refinement and development may become both more frequent and more heavily influenced by the environmental context of family, school and culture.

Horowitz's discussion (1987) extends only indirectly to a model of the development of attention. Therefore, its relation to the results of the present study are at present speculative. However, Horowitz's discussion of the function of affect and temperament in organizing behaviour is suggestive.

Affect and temperament are characterised as aspects of child functioning that are comprised primarily of non-universal behaviours and heavily influenced by environmental factors (Horowitz, 1987). Affect is characterized as central in organizing the child's behaviour during infancy. In particular, the infant is thought to use maternal affect as a means of regulating his or her behaviour in response to novel stimuli, and maternal affective signals may serve an important role in challenging cognitive situations. Additionally, there may be individual differences in the child's sensitivity to such signals. Therefore, variations in this dimension of the social environment may influence the extent to which the environment facilitates the infant's developing abilities to regulate his or her behaviour during challenging and novel tasks (Horowitz, 1987).

With respect to temperament, Horowitz (1987) notes that, although aspects of the child's temperament are thought to include a strong genetic component, the match or mismatch between these predispositions and the environment may be the most important influence on the functional significance of temperament for behaviour. Therefore, the expression and stability of such characteristics, that typically include dimensions such as task persistence, threshold of responsiveness, and activity level, may be influenced by environmental conditions. For example, the parent's response to the child's predisposition towards nonpersistence may influence the impact of this characteristic on the child's ability to regulate his or her attention during cognitive tasks.

The results of the path analyses of models of inattention, impulsivity and hyperactivity appear to be relevant to this conceptualization of processes underlying affect and temperament. The measures of attention obtained in the current study were derived from task measures, temperament measures, and parent reports of behaviours relevant to inattention, impulsivity and hyperactivity. Although there may certainly be cognitive influences on these measures, it is possible to broadly conceive problems of attention as related to problems of self-regulation of affect and/or behaviour as well. As low birthweight infants have been characterized as possessing relatively limited resources for self organization and self regulation during infancy (Rocissano & Yatchmink, 1983), and the sensitivity of caregiving has been implicated in the etiology of attention problems (Jacobvitz & Sroufe, 1987), variations in the quality of the environment may become an important source of variation in childhood attention outcomes. Furthermore, continuity in the quality of caretaking between infancy and childhood may serve to support developing attention skills or to contribute to attention problems during early childhood.

If the self-regulation of affect or behaviour is both strongly environmentally determined (Horowitz, 1987) and an important component of childhood attention problems (Campbell, 1985; Jacobvitz & Sroufe, 1987), then Horowitz's analysis is supported by the models of inattention, impulsivity and hyperactivity confirmed in the current study. The contribution of immaturity/illness to these outcomes may represent an organic or maturational component to attentional abilities that is reflected in both measures of infant development and childhood inattention, impulsivity and hyperactivity. Alternatively, it may be related to a behavioural characteristic such as nonpersistence, impulsivity or psychomotor immaturity that, in conjunction with variations in the sensitivity and quality of caregiving, has an impact on level of functioning in infancy. To the extent that these behavioural characteristics continue to be influenced by the quality of caregiving, attention problems may or may not persist during childhood.

Therefore, the results of the path analysis represent a contribution towards our understanding of processes of development that may be specific to different aspects of childhood functioning. Incorporating Horowitz's analysis, it may be possible to order these outcomes on a continuum. Motor outcome may be relatively biologically-determined during infancy and early childhood. Although environmental variations may contribute to differences in the rate and level of functioning, minimal environmental influences may be sufficient for these behaviours to be acquired, and medical risk may represent a relatively more important influence. Language outcome may consist of behaviours whose probability of acquisition is high under typical environmental conditions. However, environmental variations may make a relatively important contribution to differences in the rate of acquisition and level and quality of language skills. Finally, attention outcomes may represent behaviours whose probability of acquisition is heavily influenced by environmental influences. Medical risks associated with low birthweight are important but their influence is indirect. Immaturity/illness may contribute to difficulties in self-regulation and may be associated with certain infant characteristics that, in conjunction with inappropriate or insensitive caregiving, contribute to attention problems during childhood.

Conceptual limitations of path analysis. Path analytic techniques allow one to evaluate multivariate models of the relation between early medical risk and subsequent outcome. However, there are some conceptual limitations inherent in these techniques, and as a consequence, in the inferences drawn from the results of the analyses.

First, it is important to note that the models supported in the current study represent a good fit to the data, an adequate description of correlations and temporal relations among variables (Biddle & Marlin, 1987). However, these models do not represent the only possible explanations of the relations among the various components of each model, as competing models could be formulated and confirmed (Pedhazur, 1982). Therefore, although the results of the current study are suggestive of models of the development of language, motor and attention skills among low birthweight children, the nature of path analysis is such that these models are not the only possible representations of the relations among independent, intervening and dependent variables. Although the analyses suggest that each model represents a good fit to the data, each of these models represents only one possible network of important influences. Confirmation of the model indicates only that it provides an adquate description of the data (Biddle & Marlin, 1987; Pedhazur, 1982).

A second conceptual limitation of path analysis is related to the nonexperimental nature of the data set in the current study. Although cause-effect relations are implicit in approaches such as path analysis, their application to the current data set is only suggestive of possible causal relations. Confirmation of a causal model by way of path analyses cannot be interpretated as sufficient grounds for the presence of causal relations (Biddle & Marlin, 1987; Pedhzaur, 1982). Rather, confirmation of the models represents, instead, a correct prediction of observed relations among variables (Biddle & Marlin, 1987).

Empirical limitations of path analysis. Some final limitations of path analytic techniques relate to the various criteria used for evaluating the model and encompass both conceptual and empirical issues. LISREL analyses were used due to a practical interest in the various indices for confirmation of the model that LISREL generates. These various criteria are relatively independent of one another but, together, suggest limitations on the inferences made and the generalizability of the study results.

One of these criteria is the proportion of variance explained in the outcome variable by effects of explanatory variables (Biddle & Marlin, 1987). With respect to the current study, one relevant limitation of this criterion is related to the study design. For example, a relatively larger proportion of variance in an outcome variable (language, motor or attention outcomes, for example) may be explained when an explanatory variable (quality of the child environment, for example) is obtained concurrently. Therefore, using this criterion, the utility of the current models may be related to the design of the study, and the results may not be comparable to another study in which the childhood outcome variable and the quality of the child environment variable were separated by a time lag (Biddle & Marlin, 1987).

A second criterion for the utility of a model is the significance of pathways among components of the model. These significant pathways represent a confirmation of predicted relations among independent, intervening and dependent variables. One limitation of this criterion is the potentially problematic procedure for assessing the significance of the path coefficient. As sample size represents an obvious influence on the signficance of these coefficients, the results of the current study may not generalize to a second study, due to sample size differences (Biddle & Marlin, 1987). Similarly, as the path coefficients represent standardized beta coefficients, the generalizability of the effects reported in the current study to another study may be problematic (Pedhazur, 1982).

The goodness-of-fit indices that LISREL provide also have some inherent limitations. Although a nonsignificant Chi-square statistic indicates a good fit between the data set and the model applied to the data set, other models might also be confirmed. Furthermore, assessments of the goodness-of-fit using the Chi-square statistic are also related to sample size. Therefore, the models presented in the current study may not have been confirmed on a smaller sample and the model of language outcome may have been confirmed by way of this criterion on a larger sample.

One final important criterion for evaluating the success of a causal model is its application to a new data set or new population (Biddle & Marlin, 1987). This can be done within the context of a study whose sample is of sufficient size to be split into two subsamples. Although the sample size in the current study was sufficiently large for application of path analysis and LISREL causal modeling techniques (Biddle & Marlin, 1987), it was not sufficiently large to validate the model on a second data set. The absence of such an assessment represents an important limitation of the application of path analysis in the current study, as well as an important direction for future research. Models developed for the population of low birthweight infants represented in the current study should be applied to other populations -- both normal birthweight children and extremely low birthweight (<1000g) children. Despite the difficulty associated with establishing a linear relation between medical risk and subsequent outcome, the utility of the models developed in the current study for children at relatively lower and higher medical risk remains an important question. For example, might the effects of environmental factors be different and/or constrained among children who are more medically vulnerable than those in the current study?

## General Discussion

Contrasts among levels of analysis.

The findings of the current study contribute to several important conclusions concerning the relation between low birthweight and childhood development. Consistent with an extensive literature on the consequences of low birthweight, the current study demonstrated the absence of a direct relation between neonatal medical risk and subsequent childhood outcome. This was evident in a) medical risk subgroup comparisons, whose purpose was to identify differences in mean scores on specific aspects of childhood functioning; b) regression analyses, whose purpose was to identify predictors of these aspects of functioning; and c) explanatory analyses, whose purpose was to evaluate the relative contributions of medical risk, measures of infant development and environmental factors to childhood functioning. More significantly, perhaps, the results of the descriptive, predictive and explanatory analyses have demonstrated that our understanding of the importance of medical risk and, inevitably, environmental factors may be influenced by the manner in which we have chosen to conceptualize our research questions.

Descriptive analyses. A substantial portion of the literature has had an essentially descriptive purpose -- to compare groups of children who differed on measures of medical risk during the neonatal period, while controlling (statistically or through sample selection) for the potential influence of environmental factors. This level of analysis represents an attempt to identify and isolate the influence of medical risk, and is a logical and meaningful approach, given the well established association between poor environmental conditions and both low birthweight and less than optimal outcomes during childhood. Environmental influences, therefore, represent confounding influences that may interfere with our understanding of the role of medical risk for the development of low birthweight children. The research question formulated at this level of analysis, then, has been whether the influence of medical risk will be evident when important environmental influences are controlled.

The descriptive literature has reported a pattern of inconsistent findings concerning the role of medical risk for subsequent outcomes, even when these outcomes include specific aspects of functioning such as language, motor and attention. There have been numerous reports of differences in language outcome between low birthweight and comparison groups, although significantly lower scores have been reported among low birthweight children with severe respiratory distress or extremely low birthweight (<1000 g) children. There have been fairly consistent reports of significantly lower scores on measures of child motor skills among low birthweight children, and comparisons of medical risk subgroups have reported significantly lower scores among children with intraventricular hemorrhage and among extremely low birthweight children. Reports of differences on attention outcomes between low birthweight and comparison groups have provided an inconsistent pattern of findings.

In the current study, comparisons between medical risk subgroups that were equivalent on most important environmental influences indicated no significant differences on measures of childhood outcome. On the basis of these comparisons, one might conclude that differences in medical risk, in the absence of major differences in environmental influences, may not be important to language, motor and attention outcome among low birthweight children. However, these comparisons do not provide any information about factors that may influence variability within the group, nor any information concerning whether environmental influences may attenuate the impact of early medical risk. Therefore, descriptive analyses answer some research questions, but may leave others unanswered.

<u>Predictive analyses</u>. Predictive analyses represent a different approach to understanding the effect of medical risk and environmental factors on the development of low birthweight children. This level of analysis allows one to identify the influences of both medical risk and environmental factors, and identify factors that may influence variability within the low birthweight sample. This approach represents an attempt to identify predictors of childhood outcome from among measures of medical risk and environmental factors, and is a logical and meaningful

approach, given the practical interest in the early identification of children at continued risk. The research question formulated at this level of analysis, then, has been whether the influence of medical risk will be evident when important environmental influences are also considered as potential predictors.

The literature that has attempted to answer this research question has suggested that both medical risk and environmental factors may contribute to the prediction of childhood outcomes, although the predictive utility of medical risk and environmental factors may vary for different aspects of functioning. Environmental factors have been more consistently identified as predictors of language outcome than has medical risk, whereas medical risk has been more consistently predictive of motor outcome. Furthermore, environmental factors may represent an important predictor of child attention outcome.

Regression analyses in the current study indicated that, when the predictive utility of infant medical risk, socioeconomic status, and the quality of the environment were considered, infant socioeconomic status predicted child language; medical risk predicted motor outcome; and the quality of the infant environment predicted attention outcomes. When these measures and measures of infant developmental status were all considered as potential predictors, infant mental development and infant socioeconomic status predicted language; infant mental development predicted motor outcome, inattention and impulsivity; and the quality of the infant environment predicted hyperactivity. When these infancy measures and measures of concurrent environmental factors were considered as potential predictors, maternal vocabulary and infant mental development predicted language; infant mental development predicted motor outcome; and infant developmental status and the quality of the child environment predicted attention outcomes.

Descriptive analyses -- comparisons of medical risk subgroups -- had suggested that medical risk, in the absence of major differences in environmental influences, was unrelated to differences in childhood outcomes. However, predictive analyses, that considered the predictive utility of medical risk, were suggestive of other conclusions. Medical risk was identified as a predictor of motor outcome when measures obtained during infancy were considered as predictors. In addition, infant develcpmenal status, that could reasonably be expected to indirectly reflect medical risk, was identified as a significant predictor of most childhood outcomes.

Although environmental influences were not discernable as a result of descriptive group comparisons, they were nonetheless prominent in predictive analyses. The quality of the infant environment was a predictor of attention outcomes. Infant developmental status, that might indirectly reflect infant environmental influences, was a predictor of most childhood outcomes, as were concurrent environmental factors.

This approach allows one to identify the best predictors of specific outcomes. Infant environmental factors, rather than medical risk, may be important predictors of language and attention outcomes, and medical risk may be an important predictor of motor outcomes. However, a measure of infant development and/or a concurrent measure of the quality of the child environment yields the best prediction equation for language and attention outcomes, whereas infant developmental status may be the best predictor of childhood motor skills.

As important and informative as this level of analysis may be, there are several questions that may be unanswered and several issues that may not be considered. First, although this approach addresses the important question of prediction, it is only suggestive of underlying processses and causal mechanisms. Second, the interpretation of regression coefficients as a measure of the relative contribution of a predictor to childhood outcome is fraught with difficulties (Pedhazur, 1982). Third, the influences of variables not identified as significant predictors cannot be adequately addressed.

Explanatory analyses. Explanatory analyses represent a different approach to understanding the effect of medical risk and environmental factors on the development of low birthweight children. This level of analysis allows one to identify possible causal mechanisms underlying the relation between medical risk, environmental influences and developmental outcome, as well as the indirect and direct contributions of medical risk and environmental factors to developmental outcome. This is a logical and meaningful approach, given the conceptual interest in low birthweight children as a prototype for understanding the role of biological and environmental influences on development. Medical risk and environmental influences represent contributing influences on subsequent outcome. The research question formulated at this level of analysis, then, has been to determine the relative influence of medical risk and environmental factors to subsequent development.

Models of the development of language skills, motor skills and attention problems were formulated and evaluated. The results of these analyses are suggestive and support several conclusions that were not available from comparisons of medical risk subgroups and prediction analyses alone. These results suggest that both medical risk and environmental factors may contribute to a variety of childhood outcomes. Furthermore, the contribution of medical risk and environmental factors may be relatively more important in explaining language and attention skills than in explaining childhood motor skills. In addition, the contributions of both medical risk and environmental factors may be expressed indirectly via infant developmental status and via concurrent measures of environmental factors.

Contributions of the current study.

The results of the current study make a contribution toward our understanding of the relation between low birthweight and subsequent development. One important contribution is represented by the general finding that the effect of early medical risk for childhood functioning may vary for different domains of development. Descriptive, predictive, and explanatory analyses collectively suggest that the medical risks associated with low birthweight may be more closely related to motor outcome than to language and attention. Although there were no significant differences between medical risk subgroups on measures of motor outcome, the more medically high risk group scored significantly lower than the population mean. Similarly, immaturity/illness was identified as a significant predictor of and made an indirect contribution to childhood motor outcome. In contrast, there were no reliable differences between medical risk subgroups on measures of language and attention. Furthermore, immaturity/illness made only an indirect contribution to these childhood outcomes and environmental factors were more likely to be identified as significant predictors, and to make direct or indirect contributions to childhood outcome. The different patterns of findings for the different outcome areas may be accounted for by a number of possible explanations.

There may be continuity between early medical risks and subsequent motor outcome, as immaturity and illness may be associated with damage to the central nervous system that, in turn, has an influence on motor development. Alternatively, environmental variations may be relatively less important to individual differences in motor development during infancy and early childhood than to other aspects of functioning. Finally, the immaturity and vulnerability of the infant may be an important influence on parent perceptions of the child, and on the quality of subsequent stimulation and interactions, that may include either relatively fewer opportunities for activities involving gross and fine motor skills or the provision of inappropriate or overly stimulating activities as a means of compensating for early delays.

The different pattern of findings with respect to language outcome suggests that both the effects of medical risk and the effects of environmental stimulation may be important. Although immaturity and illness may contribute to a delay in early language development, the sequence of early language may proceed appropriately as long as perceptual systems are intact and interactions with the infant include opportunities for stimulation and communication. Environmental variations, however, appear to be especially important to individual differences in expressive and receptive vocabulary during early childhood. Maternal vocabulary may reflect level of education and, indirectly, a genetic influence on language skills. However, the provision of stimulating and appropriate play materials and experiences, as well as the direct stimulation of child vocabulary, may serve to compensate for early delays.

The pattern of findings concerning attention outcomes suggests that, although immaturity and illness may contribute indirectly to attention problems, environmental variations may have a greater functional significance for childhood attention problems than central nervous system damage that may co-occur with low birthweight. Although problems in the self-regulation of behaviour may be related to biological immaturity and early medical risk, the caregiver's sensitivity in responding to these problems may represent the most important influence on the development of attention problems.

A second contribution of the current study is support for the utility of measures of infant developmental status among high risk populations. Furthermore, the relations between measures of infant status and subsequent outcome are suggestive of continuities in development. These measures of infant developmental status, of course, may represent or reflect several aspects of the child's functioning. First, they may represent continuity in processes underlying each domain of development. Early motor and language skills may be reliably assessed by these infant measures, and therefore, be related to childhood measures of these aspects of functioning. Alternatively, measures of infant developmental status may reflect individual differences in attention skills that are continuous between infancy and childhood. Finally, the locus of continuity may not be situated in the child alone. The quality of the environment may serve to support individual differences that are first evident during infancy and continue to be evident during childhood.

Finally, the results of the current study contribute to our understanding of reported increased rates of school problems among low birthweight children. Language, motor and attention outcomes are particularly relevant, as deficits in these areas have received attention as early indicators of risk for school failure. As the children in the current study had not yet begun their formal education, the relation between language, motor and attention problems at 5 1/2 years to subsequent school achievement represents a direction for future research. However, the current study does provide information concerning factors that contribute to language, motor and attention problems within the sample. Although low birthweight may increase the likelihood of such problems, their relation to medical risk is not a direct one. Rather, the impact of medical risk on subsequent outcome is an indirect one and the provision of an appropriate and stimulating caretaking environment is associated with optimal language and attention outcomes during childhood. Therefore, problems in these areas of functioning may be amenable to environmental intervention. Although the predictive validity of early motor skills deficits for later school problems is still a focus of debate and largely an empirical question, the results of the current study suggest that the early identification of these deficits is possible and the early remediation of these problems is potentially fruitful.

Limitations of the current study.

There are several limitations of the current study. These include limitations that are related to our understanding of the effect of medical risk on childhood outcome and to our conceptualization of the role of environmental factors.

The first important limitation is related to the medical risk characteristics of the study sample. During the neonatal period, all children were regarded to be at sufficient medical risk to be admitted to neonatal intensive care. Nonetheless, the sample was quite heterogeneous from the point of view of medical risk and children at the highest medical risk were relatively infrequent in the sample. For example, the sample contained too few children born at less than 1000 g or with intraventricular hemorrhage (IVH) to permit separate analyses of these medical risk subgroups. Similarly, children for whom early illness had the most devastating consequences during infancy -- blindness and/or severe motor impairment or retardation -- were not testable as infants and, therefore, were not included in the sample of the childhood study. Therefore, the conclusions based on descriptive, predictive, and explanatory analyses of data obtained from this sample may not be generalizable to specific high medical risk subgroups such as extremely low birthweight children or infants with IVH. The investigation of the relative contributions of medical risk and environmental factors to childhood outcomes among these subgroups of children represents a direction for future research. Nonetheless, despite the heterogeneity and relatively lower medical risk of the children in the current study sample, it is important to note that immaturity/illness made an indirect contribution to all childhood outcomes. Therefore, it is possible that medical risk may be an even more important influence on the development of the most medically vulnerable infants.

A second important limitation of the current study relates to the conceptualization of environmental influences. The results of the current study suggest strongly that both medical risk and the quality of the home environment contribute to developmental outcome. Measures of maternal sensitivity and the quality of the physical and social environment are more suggestive of processes underlying developmental outcome than are status measures such as parent education and income. However, measures such as the HOME Inventory, despite their utility, remain rather global and the conclusions of the study, therefore, may be most relevant to environmental variations on such global measures. However, it may be that some variations in the quality of the caretaking environment will be most influential with respect to some aspects of childhood functioning, relatively less influential with respect to others, and possibly irrelevant to others. For example, the provision of materials for cognitive stimulation may be relatively more important for language outcome, whereas parental sensitivity in interactions with the child may be relatively more important in supporting the child's ability to regulate and maintain attention. The investigation of the differential impact of various aspects of the caretaking environment represents a direction for future research.

Conclusion.

In conclusion, the results of the current study serve as a reminder that there is much to learn about the mechanisms underlying the relations among early medical risk, environmental influences and subsequent outcomes among low birthweight children. Our understanding of these relations, however, may depend on the way in which we have formulated our research questions. In particular, obtaining data that permits the formulation of explanatory models of underlying developmental processes represents an important direction for future research.

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40) We are interested in finding out about people who you find supportive, in the emotional and social support that you receive at this point in time and under usual circumstances, when there haven't been any major family events or crises. We'd like you to describe the quality of the support you receive from the following individuals: (For each individual ask the parent to describe the nature of the support and then rate the quality of that support using the following numbers.)

Quality
1. Did not need or want support.
2. Not available because of geogrpahical distance or similar factors.
3. No support.
4 Active support, helped a little.
5. Adequate support, as much as needed.
6. Significant support.
7. Very involved. Could not have managed without their support.

Source
FAMILY
a) husband
b) your mother
c) your father
d) your sister(s)
e) your brother(s)
f) your mother-in-law
g) your father-in-law
h) other relatives (please specify)
i) FRIENDS

41) During the past six months - that is since last ______ -- have there been any recent major family events or problems, such as a death, serious illness or accident.

42) At the present time do you have any questions or concerns about S's development?

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Appendix I

<u>Letters of information and consent form</u>

Dear Parent,

For the follow-up study conducted by Ann Robson, you will be asked to participate in two home visits. Each visit will be about two hours long. As the children possess so many different skills at 5 years of age, I plan to administer several different tests. These tests will provide a great deal of information about the children's development and skills. The home visits will be scheduled at your convenience, at a time when your child will be available for testing and you will have some time to spend with me.

Visit 1

This visit will include

1)an interview with you so we can "catch up" -- update our information on your family -- and learn more about your experiences as parents and the child's current interests and activities. The interview will last for about 45 minutes to an hour.

2)a general evaluation of your child's development, obtained from a test called the McCarthy Scales of Children's Abilities. This test will provide information about the child's development in many different areas -- language, number skills, memory, puzzles and drawings, and motor skills(running, hopping, throwing) -- as well as a general score. The McCarthy is regarded as a very enjoyable test for young children and should take about 45 minutes to 1 hour.

3)I will leave some questionnaires for you to complete at your convenience. These questionnaires will concern child behaviour and behaviour problems and issues related to parenting young children. These questionnaires will take between 1 and 1 1/2 hours to complete.

Visit 2

This visit will include a number of different activities.

1)I will provide you with some feedback about your child's performance on the McCarthy Scales.

2)I will answer any questions you might have about the questionnaires before I collect the completed questionnaires and will explain the purposes of the various activities that will occur during this visit.

3)I will administer a few more tests to your child to get some further information about some specific areas of development. These areas will be:vocabulary, visual-motor skills, attention span, and matching designs and pictures. Each test will take about 10-15 minutes, so that the total testing time will, once again, be about an hour. I will be able to provide you with some feedback about these tests by the end of the visit.

4)I will ask you to complete a brief vocabulary test. The purpose of this is to provide me with an idea of the kind of language you use with your child and the relationship between your child's vocabulary and your vocabulary. Both of these bits of information can be important to an understanding of your child's development.

Your records will be confidential unless disclosure is required by law. You may refuse to answer any questions that are asked during the procedure or withdraw from participation at any time. Only those directly involved in the study will see the records for the analysis and the names of all families will be kept secret within the research group. Parents will have the opportunity to receive information about the results of the study if they so desire.

If, at any time, you have questions about any aspects of this study, please feel free to telephone me at the university, 679-2111, extension 4660, or at home, 433-4746.

Sincerely,

Ann Robson, M.A.
Ph.D. Student
Department of Psychology

Description of Questionaires

Dear parent,

The enclosed questionnaires are for you to complete at your convenience. The purpose of these questionnaires is to obtain information about issues that may not have been thoroughly discussed during the interview. Some of these questionnaires ask you to describe your child's behaviour, including behaviour problems that may exist. Other questionnaires ask you to describe you thoughts and attitudes about being a parent and your feelings and emotions. You may feel that some of the questions contained in these questionnaires are not applicable to you or your child. You may find some of the questions to be personal in nature. We would like you to answer all of the questions, but if you are uncomfortable with any particular question, please feel free to leave it blank.

The questionnaires will take between 1 and 1 1/2 hours to complete. I will attempt to answer any questions you might have before I collect the completed questionnaires during our second visit together. Thank you for your cooperation.

Sincerely,

Ann Robson, M.A.
Ph.D. Student
Department of Psychology

## Informed Consent Form

I have read the description of the follow-up study of the development of children who were low birthweight infants to be conducted by Ann Robson. I consent to participation in the study and give my consent for my child, ______________________, to participate in the study. I understand that I may refuse to answer any questions or to participate in any part of the procedure. I understand that I am free to withdraw from participation in the study at any time. I understand that the records of the study will be confidential unless disclosure is required by law. Only those directly involved in the study will see the records for the analysis and the names of all families will be kept secret within the research group. Parents will have the opportunity to receive information about the results of the study if they so desire.

______________________ ______________________

Name Signature

______________________

Date

# Appendix II

## Parent interview and HOME Inventory

General and Demographic Information

1) Date of interview and people present during interview?
2) Child's name, address, phone.
3) Child's birthdate and chronological age at interview time.

Before we begin, we'd like to update our information about your family.

4) Father's name, age, occupation and year of education.
5) Mother's name, age, occupation and year of education.
6) Has the family had any change(s) of address since last contact?
7) Names and ages of siblings.
8) Who lives in home beside child, parents and siblings? Name, age and relationship to child.
9) Are there any immediate family members not living at home? Name, where living.
10) Family income

| | | |
|---|---|---|
| 1) <$5,000 | 4) $20,000-$30,000 | 7) >$50,000 |
| 2) $5,000-$10,000 | 5) $30,000-$40,000 | |
| 3) $10,000-20,000 | 6) $40,000-$50,000 | |

Health

Next, we'd like to update our information about your child's development and health. First, I'd like to ask you some questions about S's vision, hearing and speech.

11) Has S had his/her vision examined? Age? Outcome?
 *a) (If child is blind or unable to see at all in one or both eyes) How long has S been blind or unable to see at all?
 *b) Presently does S use prescribed glasses or contact lenses?
 *c) Could S have any difficulty seeing clearly print on a page or recognizing a friend on the other side of the street (even when wearing glasses or contact lenses)?
 *d) (If Yes ) How long has S had this problem?
12) Has S had his/her hearing tested? Age? Outcome?
 *a) (If S is deaf or unable to hear at all in one or both ears) How long has S been deaf or unable to hear at all?
 *b) Does S presently use a hearing aid?
 *c) Does S have any difficulty hearing what is said in a normal conversation with one other person (even with a hearing aid)?
 *d) How long has S had this problem.
*13) Compared to other children his/her age, how well does S speak or use words? Would you say he/she is
 a) better
 b) the same
 c) worse
*14) Does S have any difficulty speaking or using words, such as stammering, stuttering, lisping or being hard to understand?
 *a) (If Yes) How long has S had this problem?
 *b) (If S is unable to communicate at all using words or speech) How long has S been unable to communicate?

Next, I'd like to update our information about your child's health and medical history. Let's begin with your general impressions of S's health now.

*15) I am going to read a set of 4 statements about the health of children. For each one, please give me the answer which best describes your child's health --

1) Strongly agree
2) Agree
3) Disagree
4) Strongly disagree

a) S's health is excellent.
b) S seems to resist illness.
c) S seems to be less healthy than other children you know.
d) When there is something going around, S usually catches it.

16) Now, we'd like to get some specific information about childhood illnesses. I'm going to read a list of illness that children have. Please tell me if S has ever experienced any of these. (Note age of occurrence, whether hospitalization was required and, if so, for how long.)

a) Asthma
b) Allergies
c) Respiratory infections or pneumonia
d) Ear infections
e) Other
f) All immunizations (DPT)

17) Has your child experienced any of the following health problems or medical events? (Note age of occurrence, whether hospitalization was required and, if so, for how long? )

*a) A head injury with loss of consciousness.
*b) A burn requiring admission to hospital.
*c) An accidental poisoning requiring admission to hospital.
*d) An accident causing broken bones or fractures.
e) High fever of unknown cause.
f) Seizures or convulsions.
g) Operations.

*18) Does S presently have any health problem or condition I haven't mentioned?

*19) Does S take any prescribed medication at regular times (daily, weeklky or monthly)?

*20) What does he/she take this medication for?

*21) What other prescribed medication does he/she take?

*22) During the past six months -- that is since last ________ -- how many times did you see or talk to any one from the following places about S? What about someone from

a) a hospital emergency
b) a medical doctor's office
c) a hospital outpatient department or clinic

Education and daycare

Now I'd like to find out about S's involvement with different kinds of programs for children.

23) Did you and your child participate in the infant program? the developmental surveillance clinic? until what date?

24) Has your child ever attended a preschool or daycare centre? (List names of centres with dates.)

25) Is your child currently attending a kindergarten, preschool or daycare centre? since when? how many hours per day? how many days per week?

Does he/she tell you about things that happen at school or what he/she does at school, or is that something you need to make a point of asking him/her about? What about when he/she has been at a friends house or to a birthday party?

The present: Activities and routines.

We are interested in finding out more about what S does when he/she is at home -- how he/she occupies his/her time, what he/she likes to play with, whether he/she plays by him/herself or with someone else. I'd like to talk about two different areas of everyday activities -- first, routines like mealtimes and so forth; second, toys, play and other activities.

26) First, let's talk about routines. One way to begin is to have you think about an average day -- yesterday, perhaps. It's usually easy to remember the main events once we get started. Let's start with things that happened when he/she first woke up

Was he/she first to get up? About what time does he/she get up in the morning? Where did he/she eat his/her breakfast and who does he/she usually eat breakfast with?

And how about lunchtimes -- how do you organize lunchtimes? Who does he/she usually eat lunch with? At breakfast and lunch is he/she willing to eat whatever you prepare or does she tell you what she wants? Does he/she usually eat what you fix whether he/she likes it or not?

What about snacks? Does he/she snack any time he/she is hungry or do you usually expect him/her to wait until meal time?

How are the evening meals organized? Do you usually feed him/her early or does the whole family eat together?

What about bedtimes? Does he/she have a usual routine after supper and for getting ready for bed? What time does he/she usually go to bed? Do he/she have any special bedtime routines or activities?

27) Now let's talk about toys, play and other activities. What activities does S enjoy during play indoors?

What kinds of toys does he/she like to play with indoors?

During the testing, we did some activities that had to do with color, size, and shape. Does S have any toys that help him/her to learn about colors, sizes and shapes?

What about learning about numbers? We did some number activities during the testing. Does S have any toys or games that help him/her to learn about numbers -- blocks, books, games, playing cards, puzzles with numbers? Is learning numbers something you would need to point out for him/her to be interested?

What about puzzles? We did some puzzles when we were together. Does S have any puzzles? Is S able to keep track of all the pieces or are puzzle pieces often missing when he/she decides to play with puzzles?

What about art and craft kinds of activities? Does S play with clay, paint, play dough or crayons here at home? Does he/she enjoy drawing, coloring, cutting and pasting, stringing beads?

We did a listening activity with a small toy xylophone during the testing. What about musical activities? Does S know any songs or nursery rhymes or TV commercials? Where did he/she learn them or who taught him/her. Does S enjoy listening to or singing along with music? Does he/she enjoy listening to the radio or your records and tapes or does he/she have any special records or tapes of his/her own? Does he/she use your record/tape player or have one of his/her own? Does S have any musical instruments -- either toy or real?

During the testing I asked S to name as many different animals as he/she could think of? Does S have any toys that help him/her to learn about animals -- toy animals, books about animals, circus or zoo games, animal puzzles?

Does S enjoy looking at books? Is that something S does on his/her own or is it he/she enjoys doing with other people? When you look at books together has S expressed any interest in learning that a certain letter makes a certain sound or in learning to read or is that something you would have to point out in order for him/her to be interested? Is S interested in learning to recognize or write his/her own name? Does S have any toys or activities that help him/her to learn the alphabet?

Do you use the library or is it easier to buy books? How about you? Do you ever have any time for reading books? How about a daily newspaper or a magazine subscription?

28) What activities does S enjoy during play outdoors? What kinds of toys does he/she like to play with outdoors?

29) What kinds of activities do you and your child enjoy doing together? Are you able to find some time to spend together each day -- watching TV together or looki g at a book?

Young children demand attention and you ave a lot of other things to do. How do you arrange things whi.e you are doing something that keeps you busy -- like doing iishes? What about TV? When you are at home with small children you can find the TV a lot of company. Do you usually leave it on all day or just turn it on for special programs? Does S enjoy TV? What are S's favorite TV programs?

30) What kinds of activities does your child enjoy doing with other family members?

What about routine kinds of activities. Does S go along with you when you go shopping or grocery shopping? How often does he/she go along - how many times a month, let's say. I guess S sees a lot of things advertised on TV. Does he/she want to get some of these things when you go to the store. Now that food prices are so high are you able to let him select certain things at the grocery store?

Give some examples of places you go and take the children with you --the movies, to a zoo or animal park, to a restaurant, to a museum? How often? Do you ever have an occasion to make a longer trip -- to visit relatives or take a holiday? How often?

*31) Is S limited in any way in the kind or amount of ordinary play or activity he/she can do with other children?
*32) (If YES to 30) Describe in what way S is limited?
*33) How long has S been limited in this way?
a) less than 1 month
b) 1-6 months
c) more than 6 months
d) always
e) don't know
34) How does S play and/or get along with other children? Does S prefer to play alone or play together with other people. What about tidying up after playing -- Do you pick up the toys yourself or try to get him to do it each day? Is it something you would rather have him do than do it yourself? At school, each teacher often has different rules: There are some who have rules about manners, some who stress helping, taking turns, sharing, politeness, not to fight, or to say "please" when asking for something. What is important to you for S right at this time when he/she is five years old? Has this come up yet? How do you usually handle it?
35) What have you found to be the most effective approach to discipline with S?
36) How often is it necessary to discipline S ?
37) Is the approach to discipline you use with S an approach you use with all your children?
Does S ever express negative feelings to you or have a tantrum? What happens when he/she does or how would you handle it if he /she did?
Does S every get negative or angry enough to hit you? How do you or would you handle that or how do you think a parent should handle that sort of thing?
How often do you have to spank S?
*38) During the past 6 months - that is since last __________ -- do you think that S has had any emotional or behavioural problems?
(If YES to 38) During that time, did he/she tend to have more emotional or behavioural problems than other boys/girls/ of his/her age?
* 39) During the past six months -- that is since last ________ -- how many times did you see or talk to any one from the following places about S ? What about someone from
a) the Family and Children's Services
b) psychologist or social worker?
c) some other organization or individual I haven't mentioned

42, We are interested in finding out about people who you find supportive, in the emotional and social support that you receive at this point in time and under usual circumstances, when there haven't been any major family events or crises. We'd like you to describe the quality of the support you receive from the following individuals: (For each individual ask the parent to describe the nature of the support and then rate the quality of that support using the following numbers.)

Quality
1. Did not need or want support.
2. Not available because of geogrpahical distance or similar factors.
3. No support.
4 Active support, helped a little.
5. Adequate support, as much as needed.
6. Significant support.
7. Very involved. Could not have managed without their support.

Source
FAMILY
a) husband
b) your mother
c) your father
d) your sister(s)
e) your brother(s)
f) your mother-in-law
g) your father-in-law
h) other relatives (please specify)
i) FRIENDS

41) During the past six months - that is since last ______ -- have there been any recent major family events or problems, such as a death, serious illness or accident.
42) At the present time do you have any questions or concerns about S's development?

Bettye M. Caldwell and Robert H. Bradley

Family Name ______ ______________ Date __________ Visitor ______________

Child's Name ______________________ Birthdate __________ Age ________ Sex ________

Caregiver for visit ______________________ Relationship to child ______________

Family composition ________________________________________________
(Persons living in household, including sex and age of children)

Family Ethnicity ______________ Language Spoken __________ Maternal Education __________ Paternal Education ______

Is Mother employed? ______ Type of work when employed ______________ Is Father employed? ______ Type of work when employed __________

Address ______________________________________ Phone ______________

Current child care arrangements ________________________________________

Summarize past year's arrangements ________________________________________

Caregiver for visit ______________________ Other persons present ______________

SUMMARY

| Subscale | Score | Percentile Range | | |
|---|---|---|---|---|
| | | Lowest Fourth | Middle Half | Upper Fourth |
| I. LEARNING STIMULATION | | 0-2 | 3-9 | 10-11 |
| II. LANGUAGE STIMULATION | | 0-4 | 5-6 | 7 |
| III. PHYSICAL ENVIRONMENT | | 0-3 | 4-6 | 7 |
| IV. WARMTH AND AFFECTION | | 0-3 | 4-5 | 6-7 |
| V. ACADEMIC STIMULATION | | 0-2 | 3-4 | 5 |
| VI. MODELING | | 0-1 | 2-3 | 4-5 |
| VII. VARIETY IN EXPERIENCE | | 0-4 | 5-7 | 8-9 |
| VIII. ACCEPTANCE | | 0-2 | 3 | 4 |
| TOTAL SCORE | | 0-29 | 30-45 | 46-55 |

For rapid profiling of a family, place an X in the box that corresponds to the raw score

HOME Inventory (Preschool)

Place a plus (+) or minus (-) in the box alongside each item if the behavior is observed during the visit or if the parent reports that the conditions or events are characteristic of the home environment. Enter the subtotals and the total on the front side of the Record Sheet.

I. LEARNING STIMULATION

| | |
|---|---|
| 1. Child has toys which teach color, size, shape. | |
| 2. Child has three or more puzzles. | |
| 3. Child has record player and at least five children's records. | |
| 4. Child has toys permitting free expression. | |
| 5. Child has toys or games requiring refined movements. | |
| 6. Child has toys or games which help teach numbers. | |
| 7. Child has at least 10 children's books. | |
| 8. At least 10 books are visible in the apartment. | |
| 9. Family buys and reads a daily newspaper. | |
| 10. Family subscribes to at least one magazine. | |
| 11. Child is encouraged to learn shapes. | |
| Subtotal | |

II. LANGUAGE STIMULATION

| | |
|---|---|
| 12. Child has toys that help teach the names of animals. | |
| 13. Child is encouraged to learn the alphabet. | |
| 14. Parent teaches child simple verbal manners (please, thank you). | |
| 15. Mother uses correct grammar and pronunciation. | |
| 16. Parent encourages child to talk and takes time to listen. | |
| 17. Parent's voice conveys positive feeling to child. | |
| 18. Child is permitted choice in breakfast or lunch menu. | |
| Subtotal | |

III. PHYSICAL ENVIRONMENT

| | |
|---|---|
| 19. Building appears safe. | |
| 20. Outside play environment appears safe. | |
| 21. Interior of apartment not dark or perceptually monotonous. | |
| 22. Neighborhood is esthetically pleasing. | |
| 23. House has 100 square feet of living space per person. | |
| 24. Rooms are not overcrowded with furniture. | |
| 25. House is reasonably clean and minimally cluttered. | |
| Subtotal | |

IV. WARMTH AND ACCEPTANCE

| | |
|---|---|
| 26. Parent holds child close 10-15 minutes per day. | |
| 27. Parent converses with child at least twice during visit. * | |
| 28. Parent answers child's questions or requests verbally. * | |
| 29. Parent usually responds verbally to child's speech. * | |
| 30. Parent praises child's qualities twice during visit. * | |
| 31. Parent caresses, kisses, or cuddles child during visit. * | |
| 32. Parent helps child demonstrate some achievement during visit. * | |
| Subtotal | |

V. ACADEMIC STIMULATION

| | |
|---|---|
| 33. Child is encouraged to learn colors. | |
| 34. Child is encouraged to learn patterned speech (songs, etc.). | |
| 35. Child is encouraged to learn spatial relationships. | |
| 36. Child is encouraged to learn numbers. | |
| 37. Child is encouraged to learn to read a few words. | |
| Subtotal | |

VI. MODELING

| | |
|---|---|
| 38. Some delay of food gratification is expected. | |
| 39. TV is used judiciously. | |
| 40. Parent introduces visitor to child. | |
| 41. Child can express negative feelings without reprisal. | |
| 42. Child can hit parent without harsh reprisal. | |
| Subtotal | |

VII. VARIETY IN EXPERIENCE

| | |
|---|---|
| 43. Child has real or toy musical instrument. | |
| 44. Child is taken on outing by family member at least every other week. | |
| 45. Child has been on trip more than fifty miles during last year. | |
| 46. Child has been taken to a museum during past year. | |
| 47. Parent encourages child to put away toys without help. | |
| 48. Parent uses complex sentence structure and vocabulary. | |
| 49. Child's art work is displayed some place in house. | |
| 50. Child eats at least one meal per day with mother and father. | |
| 51. Parent lets child choose some foods or brands at grocery store. | |
| Subtotal | |

VIII. ACCEPTANCE

| | |
|---|---|
| 52. Parent does not scold or derogate child more than once. * | |
| 53. Parent does not use physical restraint during visit. * | |
| 54. Parent neither slaps nor spanks child during visit. | |
| 55. No more than one instance of physical punishment during past week. | |
| Subtotal | |

*For complete wording of items, please refer to the Administration Manual.

COMMENTS

# Appendix III

## Missing data analyses

<u>Missing data subgroups</u>. Mariscuilo and Levin (1983) have described an approach to missing data. The first step is to determine if the missing value pattern is random; this is done by comparing groups with complete and missing values on an individual measure. For example, children who did not play the X Task could be compared to those children who did on measures of cognitive and motor outcome, demographic status, environmental factors, and child behaviour.

There were several disadvantages to this approach in the current study. There was a large number of children with complete data on cognitive and motor ($n$=85), attention task ($n$=83), demographic status ($n$=86), and HOME Inventory ($n$=86) measures. Comparisons between groups designated by missing values on individual measures would have resulted in a large number of comparisons between groups of very disparate n's. Furthermore, missing values existed for a number of different reasons. For example, scores for the X Task were missing in the case of either failure to meet the pretest criteria or refusal to play the game. Alternatively, some measures of demographic status would be missing in the case of single parent families.

Missing values for maternal vocabulary score ($n$=58 completed) and parent reports of child behaviour ($n$=77 s cs of BSQ and PSI questionnaires completed) accounted for most of the missing data. Therefore, it seemed that the most meaningful comparisons focused on these measures. Two missing data analyses were conducted. One was a comparison between children whose data sets included maternal vocabulary test scores and those whose data sets included missing values on the maternal vocabulary test. The second was a comparison between children whose data sets included scores on the Behavioral Style Questionnaire and the Parenting Stress Index and those whose data sets included missing values on these questionnaire measures. For each missing data analysis, two subgroups were designated and compared on cognitive, motor, attention task and behaviour rating measures, and on child demographic and environmental measures. Within each missing data analysis, T-tests were used to compare the two subgroups; the experimentwise error rate was set at .1; due to the number of comparisons, the error rate per comparison was .006.

The comparison between children whose mothers had completed the maternal vocabulary measure and children whose mothers had not is presented in Appendix III-A. T-tests indicated that there were no statistically significant differences between the two groups on childhood outcome, demographic and environmental measures. Children whose mothers did not complete the maternal vocabulary measure tended to have higher ratings on inattention and impulsivity and, according to parent reports, were more negative in mood and distractible/hyperactive.

The comparison between children whose mothers had completed the questionnaires and children whose mothers had not is presented in Appendix III-B. T-tests indicated that there were no statistically significant differences between the two groups on childhood outcome, demographic and environmental measures. Children whose mothers did not complete the questionnaires tended to have higher ratings on inattention, implulsivity and hyperactivity.

These results suggest that the pattern of missing values may not have been completely random. Children whose mothers did not complete the vocabulary test may have presented behaviour that made the administration of the vocabulary test difficult or impossible due to time constraints. Similarly, children whose mothers did not complete the questionnaires may have presented behaviour during testing or in the home that made the completion of the questionnaires difficult for the mothers.

Neither the deletion of cases nor the estimation of missing values seemed appropriate. The deletion of cases with missing values would have reduced the sample to 49 children, resulting in a loss of information and statistical power in subsequent analyses. Estimation procedures depend on the randomness of the pattern of missing values and each procedure may yield a different estimate for the missing value (Mariscuilo & Levin, 1983). In addition, the HOME inventory, rather than the maternal vocabulary score, was the primary measure of the quality of the child environment.

Analyses that included maternal vocabulary as a predictor could be conducted separately. Finally, there were multiple measures of most constructs of interest. For example, in the case of "attention", measures were obtained from different tasks, examiner ratings of child behaviour, and parent reports of child behaviour obtained from questionnaires. If Child A's mother did not complete the questionnaires, measures of attention existed in the task scores and examiner ratings. Therefore, although there were missing values, alternative measures of the construct of interest usually existed.

Therefore, a pairwise deletion of cases was used in subsequent correlation analyses. Aggregate scores for each child were derived from existing measures of the construct of interest. The disadvantages of this approach seemed less problematic than those associated with either the deletion of cases or the estimation of missing values.

Appendix III-A

<u>Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data</u>

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | *t* (df) |
| Cognitive and motor measures | | | | |
| McCarthy Scales | | *n*=58 | *n*=30 | |
| GCI | *M* | 102.6 | 95.7 | 1.90 (86) |
| | *SD* | 15.3 | 17.5 | |
| Verbal | *M* | 53.6 | 48.5 | 1.94 |
| | *SD* | 11.3 | 12.2 | |
| Perceptual-Performance | *M* | 49.3 | 48.7 | .29 |
| | *SD* | 9.5 | 10.8 | |
| Quantitative | *M* | 50.1 | 45.2 | 2.65* |
| | *SD* | 8.5 | 7.5 | |
| Memory | *M* | 49.7 | 43.9 | 2.35* |
| | *SD* | 10.7 | 11.3 | |
| | | *n*=58 | *n*=31 | |
| Motor | *M* | 44.6 | 41.4 | 1.25 (87) |
| | *SD* | 11.2 | 11.9 | |

Appendix III-A cont'd.

Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data

| | | Subgroup Complete Data | Subgroup Missing Data | t (df) |
|---|---|---|---|---|
| VMI | | n=57 | n=27 | |
| | M | 90.6 | 88.5 | .82 (83) |
| | SD | 10.0 | 12.9 | |
| PPVT-R | | n=57 | n=29 | |
| | M | 103.1 | 95.5 | 2.14* (84) |
| | SD | 14.4 | 17.4 | |
| Attention task measures | | | | |
| Get-the-X-Game | | n=57 | n=26 | |
| d' score | M | .01 | -.02 | .07 (81) |
| | SD | 1.57 | 1.59 | |
| i score (%) | M | 20.30 | 19.61 | .15 |
| | SD | 19.46 | 20.42 | |
| MFFT | | n=57 | n=27 | |
| Latency | M | 7.55 | 8.08 | -.36 (82) |
| | SD | 4.30 | 9.17 | |
| Errors | M | 22.75 | 22.67 | .05 |
| | SD | 7.20 | 7.62 | |

Appendix III-A cont'd.

<u>Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data</u>

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | *t* (df) |
| PPVT-R | | *n*=55 | *n*=26 | |
| Latency | *M* | 4.18 | 3.78 | .73 (79) |
| | *SD* | 2.59 | 1.47 | |
| Behaviour measures | | | | |
| Ratings (%) | | *n*=58 | *n*=30 | |
| Inattention | *M* | 48.79 | 61.[illegible]3 | $-2.94^{*}$ (86) |
| | *SD* | 18.93 | 19.07 | |
| Impulsivity | *M* | 40.86 | 52.67 | $-2.61^{*}$ |
| | *SD* | 18.09 | 23.63 | |
| Hyperactivity | *M* | 42.24 | 51.33 | $-2.23^{+}$ |
| | *SD* | 17.68 | 18.89 | |
| BSQ scores | | *n*=57 | *n*=20 | |
| Activity | *M* | 3.40 | 3.57 | -1.01 (75) |
| | *SD* | .63 | .67 | |
| Rhythmicity | *M* | 2.68 | 2.99 | -1.91 |
| | *SD* | .65 | .58 | |

Appendix III-A cont'd.

Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | *t* (df) |
| Approach | *M* | 2.92 | 2.83 | .53 |
| | *SD* | .68 | .65 | |
| Adaptability | *M* | 2.52 | 2.86 | -2.04* |
| | *SD* | .58 | .75 | |
| Intensity | *M* | 4.21 | 4.47 | -1.44 |
| | *SD* | .69 | .64 | |
| Mood | *M* | 3.00 | 3.30 | -1.90 |
| | *SD* | .59 | .63 | |
| Persistence | *M* | 2.92 | 3.05 | - .65 |
| | *SD* | .69 | .91 | |
| Distractibility | *M* | 3.92 | 4.25 | -2.14* |
| | *SD* | .62 | .48 | |
| Threshold | *M* | 3.82 | 4.00 | -1.09 |
| | *SD* | .58 | .75 | |
| PSI scores | | *n*=57 | *n*=23 | |
| Adaptability | *M* | 23.32 | 25.13 | -1.52 (78) |
| | *SD* | 4.74 | 5.08 | |

Appendix III-A cont'd.

Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | _t_ (df) |
| Acceptability | _M_ | 12.53 | 13.87 | -1.53 |
| | _SD_ | 3.54 | 3.62 | |
| Demandingness | _M_ | 17.42 | 18.91 | -1.47 |
| | _SD_ | 3.96 | 4.44 | |
| Mood | _M_ | 9.47 | 11.30 | -2.92* |
| | _SD_ | 2.41 | 2.84 | |
| Distractibility/ Hyperactivity | _M_ | 20.21 | 23.57 | -2.69* |
| | _SD_ | 5.01 | 5.13 | |
| Reinforcing | _M_ | 10.04 | 11.43 | -1.65 |
| | _SD_ | 2.67 | 4.84 | |
| Demographic measures | | _n_=58 | _n_=31 | |
| Maternal age | _M_ | 31.6 | 31.6 | .04 |
| | _SD_ | 4.3 | 3.4 | |
| Maternal education | _M_ | 12.2 | 12.4 | - .42 |
| | _SD_ | 2.0 | 1.6 | |

Appendix III-A cont'd.

Means and standard deviations of child outcome, questionnaire, demographic, and environmental measures for children with and without completed maternal vocabulary data

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | t (df) |
| Paternal | | n=57 | n=30 | |
| education | M | 12.4 | 13.3 | -1.62 (85) |
| | SD | 2.4 | 2.8 | |
| Occupational | | n=58 | n=32 | |
| status | M | 41.9 | 43.0 | - .34 (88) |
| | SD | 12.2 | 17.2 | |
| Income | | n=57 | n=32 | |
| | M | 36,000 | 39,000 | |
| | SD | 6,500 | 7,000 | |
| Environmental measure | | n=57 | n=29 | |
| HOME Inventory | M | 39.3 | 38.0 | .98 (84) |
| | SD | 5.1 | 6.9 | |

* = p <.01. ** = p <.001.

Appendix III-B

Means and standard deviations of child outcome, demographic, and environmental measures for children with and without completed questionnaire data.

| | | Subgroup: Complete Data | Subgroup: Missing Data | *t* (df) |
|---|---|---|---|---|
| Cognitive and motor measures | | | | |
| McCarthy Scales | | | | |
| GCI | *M* | 101.3 | 92.4 | 1.70 (85) |
| | *SD* | 15.9 | 18.3 | |
| Verbal | *M* | 52.3 | 47.5 | 1.25 |
| | *SD* | 11.5 | 12.8 | |
| Perceptual-Performance | *M* | 49.7 | 45.4 | 1.36 |
| | *SD* | 9.8 | 10.5 | |
| Quantitative | *M* | 49.0 | 44.1 | 1.80 |
| | *SD* | 8.5 | 8.1 | |
| Memory | *M* | 48.4 | 42.4 | 1.69 |
| | *SD* | 11.3 | 9.9 | |
| | | *n*=76 | *n*=12 | |
| Motor | *M* | 44.2 | 39.0 | 1.46 (86) |
| | *SD* | 11.7 | 9.6 | |

Appendix III-B cont'd.

Means and standard deviations of child outcome, demographic, and environmental measures for children with and without completed questionnaire data.

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | t (df) |
| VMI | | n=75 | n=9 | |
| | M | 90.3 | 86.8 | .90 (82) |
| | SD | 10.5 | 15.8 | |
| PPVT-R | | n=75 | n=10 | |
| | M | 101.6 | 92.2 | |
| | SD | 14.8 | 21.9 | |
| Attention task measures | | | | |
| Get-the-X-Game | | n=74 | n=8 | |
| d' score | M | - .05 | .32 | - .63 (80) |
| | SD | 1.60 | 1.29 | |
| i score (%) | M | 20.09 | 21.61 | - .20 (80) |
| | SD | 19.86 | 19.35 | |
| MFFT | | n=75 | n=8 | |
| Latency | M | 7.89 | 6.19 | .73 (81) |
| | SD | 6.48 | 3.76 | |

Appendix III-B cont'd.

Means and standard deviations of child outcome, demographic, and environmental measures for children with and without completed questionnaire data.

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | $t$ (df) |
| MFFT | | | | |
| Errors | $M$ | 23.04 | 19.63 | 1.26 |
| | $SD$ | 7.45 | 5.61 | |
| PPVT-R | | $n$=72 | $n$=8 | |
| Latency | $M$ | 4.04 | 3.46 | .70 (78) |
| | $SD$ | 2.29 | 1.46 | |
| Behaviour measures | | | | |
| Ratings (%) | | $n$=76 | $n$=11 | |
| Inattention | $M$ | 51.05 | 66.36 | $-2.45^{*}$ (85) |
| | $SD$ | 19.84 | 15.02 | |
| Impulsivity | $M$ | 43.16 | 57.27 | $-2.14^{*}$ |
| | $SD$ | 19.95 | 24.12 | |
| Hyperactivity | $M$ | 43.42 | 57.27 | $-2.38^{*}$ |
| | $SD$ | 17.93 | 19.02 | |

Appendix III-B cont'd.

Means and standard deviations of child outcome, demographic, and environmental measures for children with and without completed questionnaire data.

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | *t* (df) |
| Demographic measures | | *n*=75 | *n*=13 | |
| Maternal age | *M* | 31.8 | 30.2 | 1.36 (86) |
| | *SD* | 3.9 | 4.2 | |
| Maternal education | *M* | 12.3 | 12.4 | - .21 |
| | *SD* | 2.0 | 1.4 | |
| Paternal education | *M* | 12.6 | 12.8 | - .32 (84) |
| | *SD* | 2.6 | 1.6 | |
| Occupational status | *M* | 42.7 | 37.0 | 1.40 (87) |
| | *SD* | 14.3 | 6.3 | |
| Income | *M* | 38,000 | 35,000 | .62 |
| | *SD* | 6,500 | 8,000 | |

Appendix III-B cont'd.

Means and standard deviations of child outcome, demographic, and environmental measures for children with and without completed questionnaire data.

| | | Subgroup | | |
|---|---|---|---|---|
| | | Complete Data | Missing Data | $t$ (df) |
| Environmental measure | | $n$=75 | $n$=10 | |
| HOME Inventory | $M$ | 38.8 | 38.8 | - .01 (83) |
| | $SD$ | 5.6 | 6.8 | |
| Maternal | | $n$=56 | $n$=1 | |
| vocabulary | $M$ | 96.7 | 99.0 | |
| | $SD$ | 14.0 | | |

+ = $p$ <.05. * = $p$ <.01. ** = $p$ <.001.

# Appendix IV-A

## Intercorrelations among infant predictor measures

| Measure | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Birthweight | .81 | -.56 | -.77 | -.40 | .04 | .33 | .25 | -.08 | .03 | .08 | .05 | .04 |
| 2 Gestational age | | -.62 | -.79 | -.60 | .05 | .33 | .25 | .05 | .01 | -.02 | .04 | .02 |
| 3 Morbidity | | | .84 | .72 | -.07 | -.26 | -.18 | .03 | .15 | .05 | .12 | .05 |
| 4 Days in hospital | | | | .73 | -.09 | -.30 | -.23 | -.02 | .02 | -.04 | -.02 | -.06 |
| 5 RDS severity | | | | | -.02 | -.22 | -.04 | -.13 | .11 | .10 | .06 | .07 |
| 6 Maternal age | | | | | | .48 | .67 | .42 | .34 | .30 | .41 | .40 |
| 7 Maternal education | | | | | | | .66 | .27 | .40 | .36 | .37 | .36 |
| 8 Paternal education | | | | | | | | .35 | .55 | .49 | .49 | .48 |
| 9 Occupational status | | | | | | | | | .41 | .41 | .36 | .42 |
| 10 HOME (7 month) | | | | | | | | | | .74 | .82 | .77 |
| 11 HOME (12 month) | | | | | | | | | | | .71 | .87 |
| 12 Sensitivity (7 month) | | | | | | | | | | | | .78 |
| 13 Sensitivity (12 month) | | | | | | | | | | | | |

For $n=90$, correlation coefficients with an absolute value greater than .26 are significantly different from 0 at $p<.001$

# Appendix IV-B

## Factor loadings for the infant predictor measures

| Measure | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| Days in hospital | .95008 | -.03023 | -.08042 |
| Gestational age | -.87954 | .02074 | .10118 |
| Morbidity | .85379 | .12959 | -.10368 |
| Birthweight | -.83113 | .09717 | .02946 |
| RDS severity | .76677 | .13182 | -.09159 |
| Sensitivity (12 month) | .00104 | .90266 | .24253 |
| HOME (12 month) | .00222 | .88380 | .21993 |
| Sensitivity (7 month) | .05057 | .84696 | .31253 |
| HOME (7 month) | .08192 | .84439 | .32896 |
| Occupational status | -.01661 | .20448 | .84113 |
| Paternal education | -.18369 | .36560 | .77397 |
| Maternal education | -.30742 | .21225 | .71608 |
| Maternal age | .01191 | .26599 | .54867 |
| Percent of variance | 37.0 | 29.2 | 8.1 |